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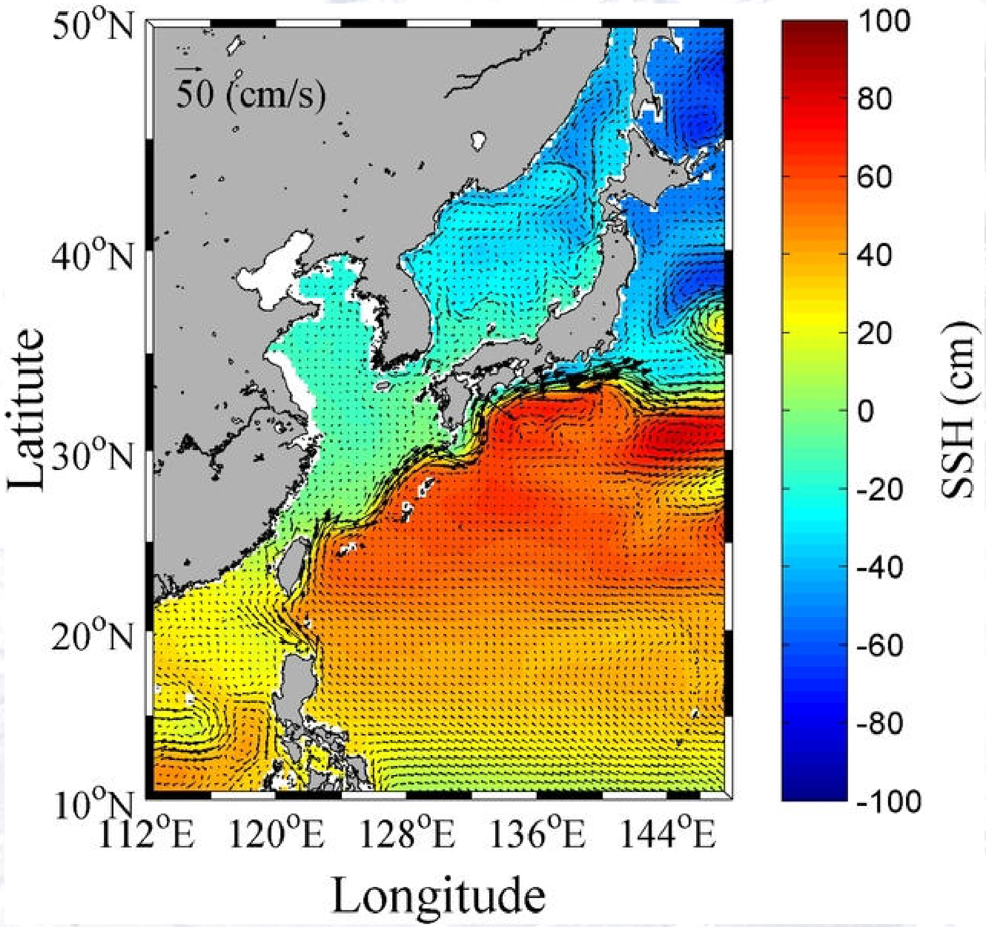
台灣周遭海域長期變化與影響



曾于恒、郭怡君、紹允銓
國立臺灣大學海洋研究所

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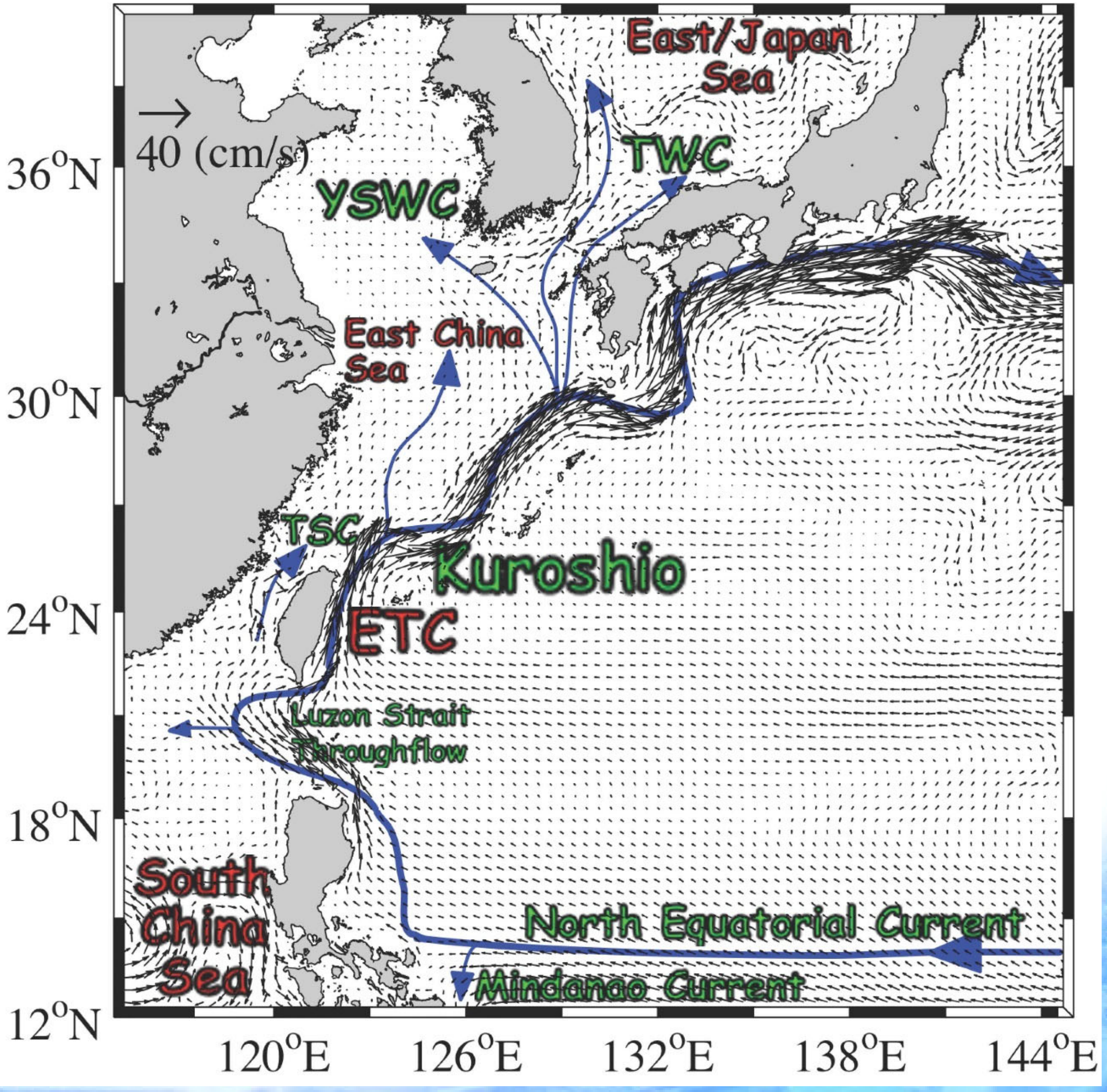
Ocean circulation in the vicinity of Taiwan



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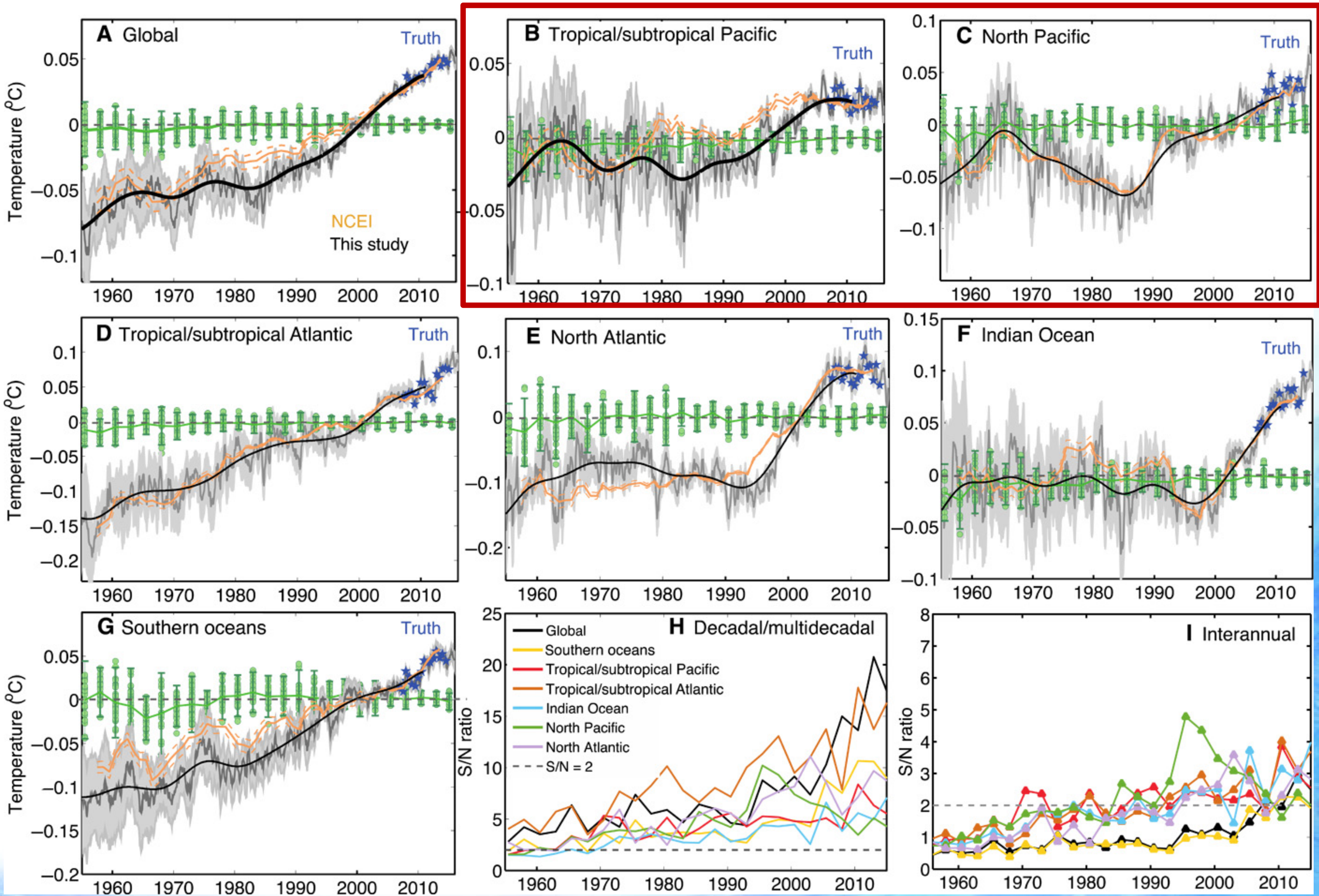
Warming of the Global Ocean

Cheng et al. (2015)

Heat content increased by 33.5×10^{22}J (1960-2015, 36.5% 0-300m)



→The Pacific Ocean has been significantly warming after 1980s

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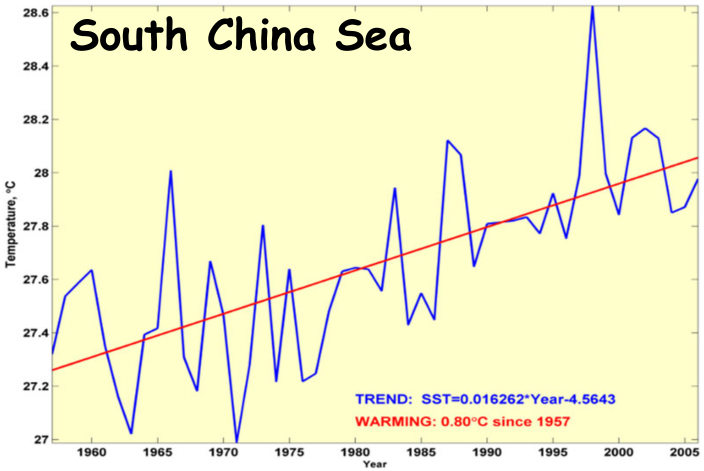
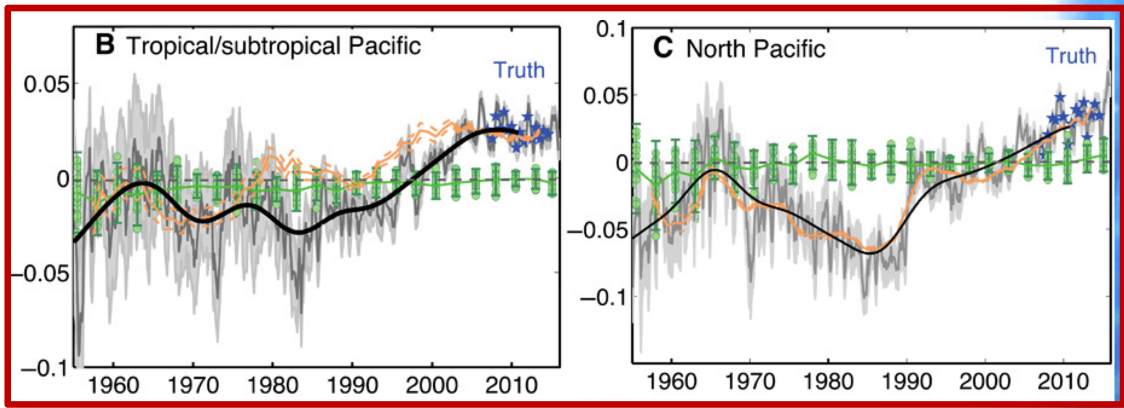
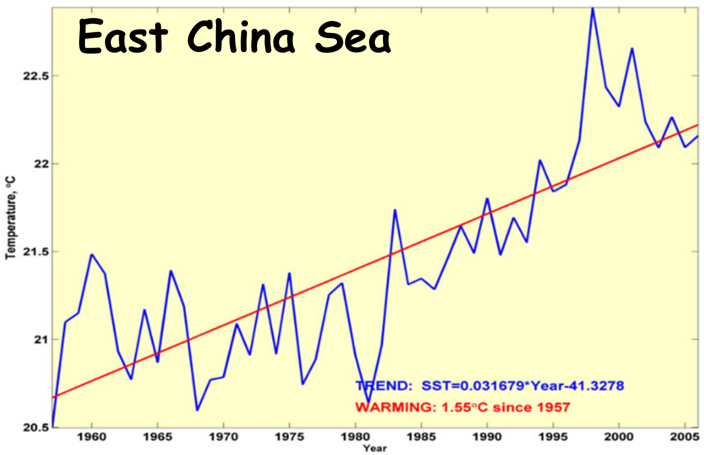
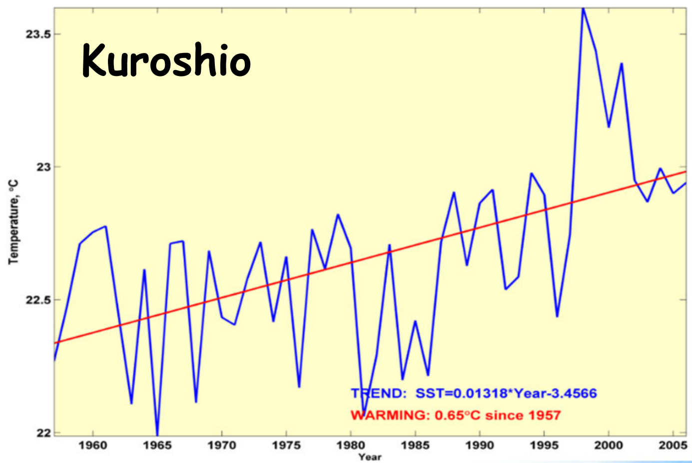
Annual SST change in the vicinity of Taiwan









Larger warming trend

Similarity: ENSO variability
Difference: decadal change

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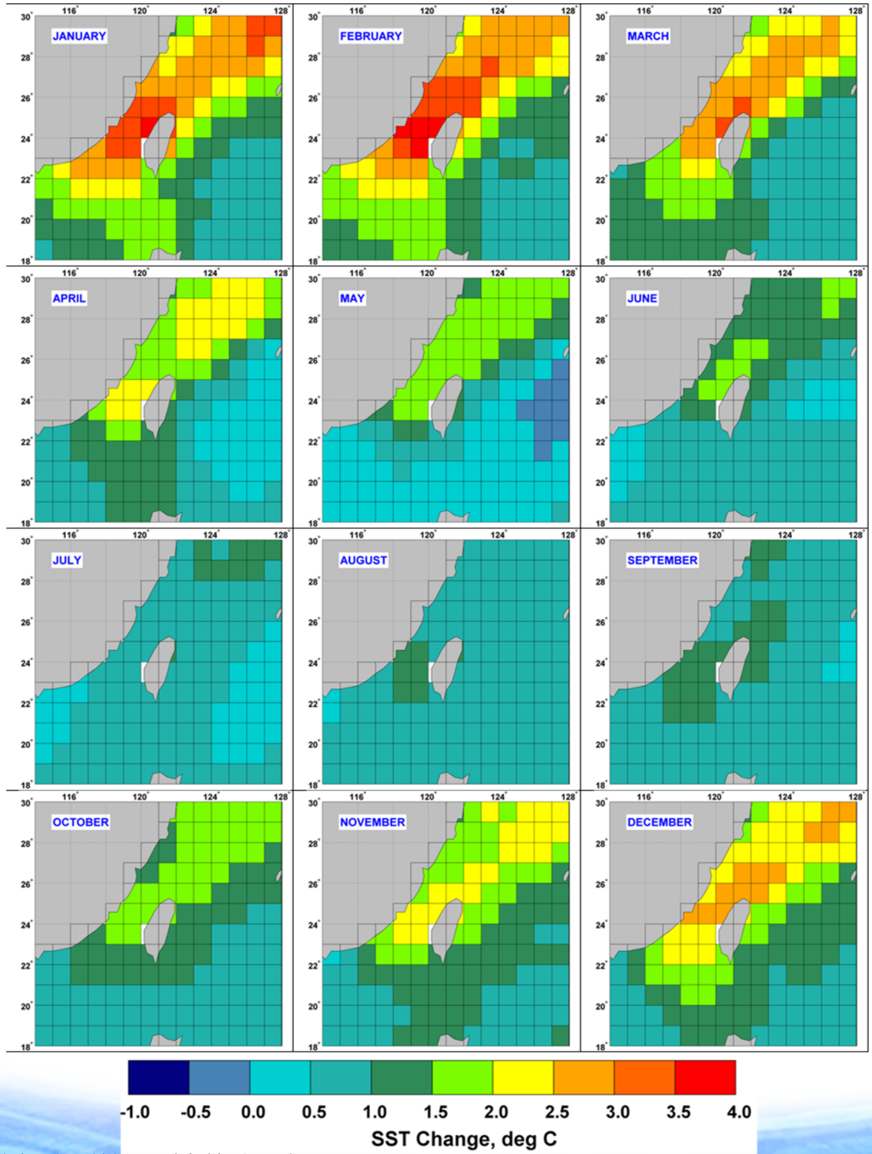
Regional distribution of SST trend (1957-2011)



臺灣氣候變遷科學報告 (2014)

Fastest warming: Winter (January-March)
Slowest warming: Summer (July-September)

Largest warming trend along the continental shelf

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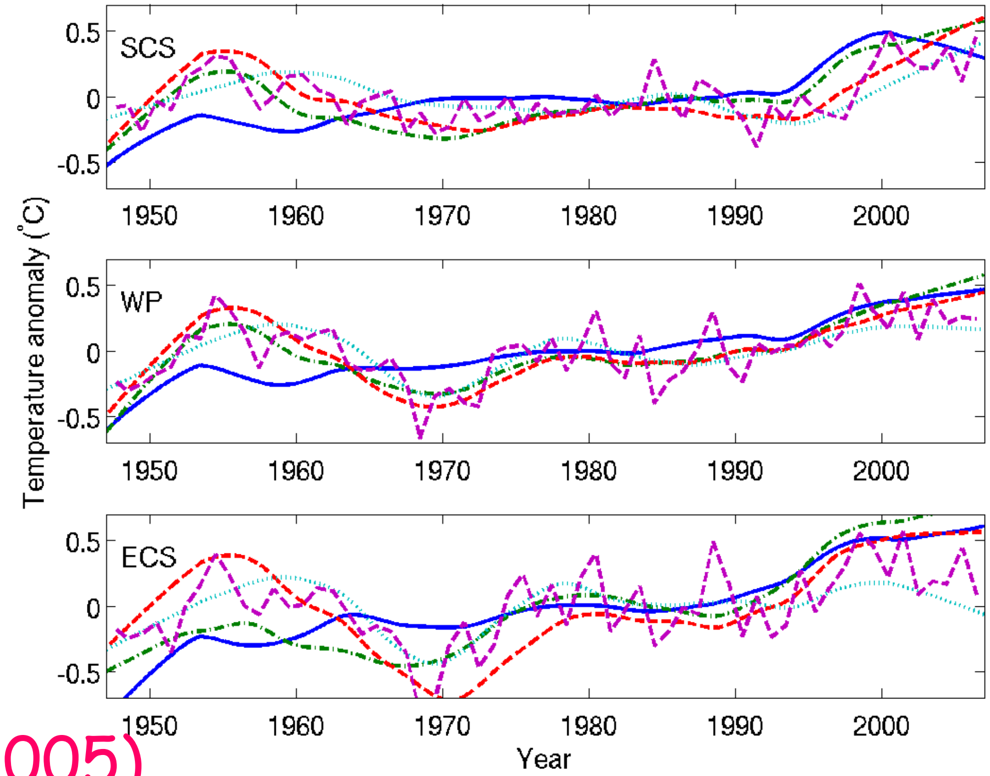
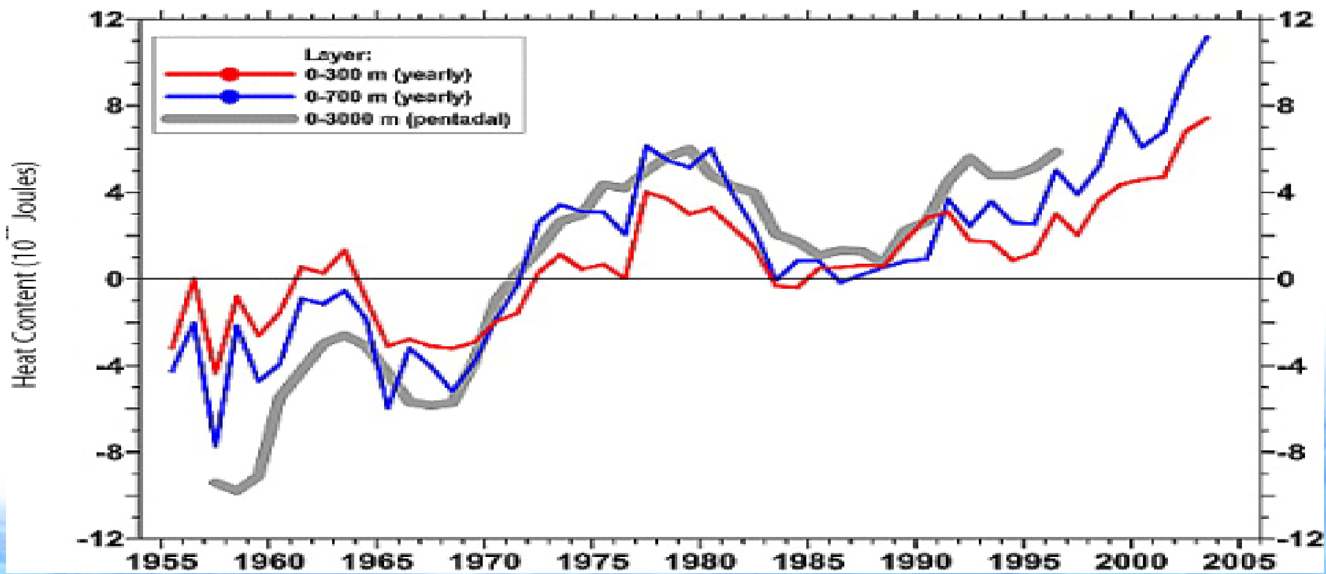
LOESS analysis of the ocean subsurface temperature based on Ishii analysis (Ishii et al., 2006)



Heat content (Levitus et al., 2005)



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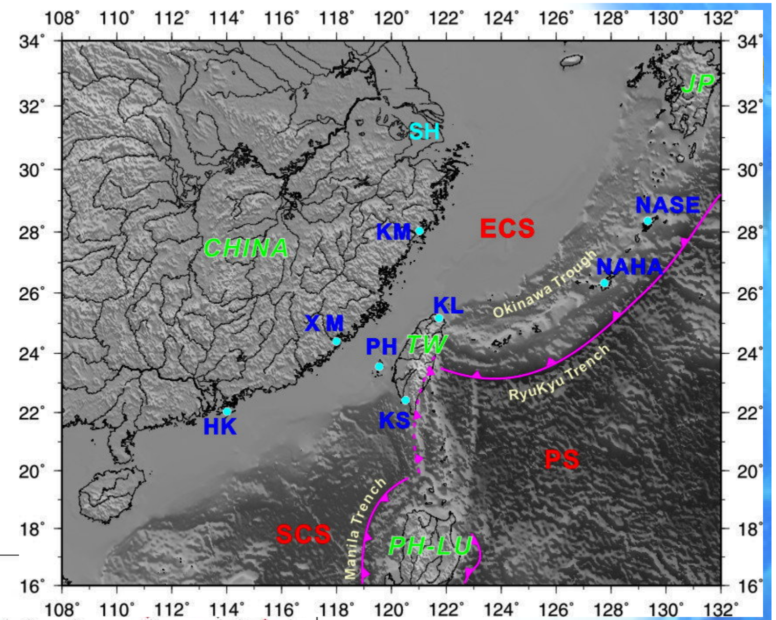
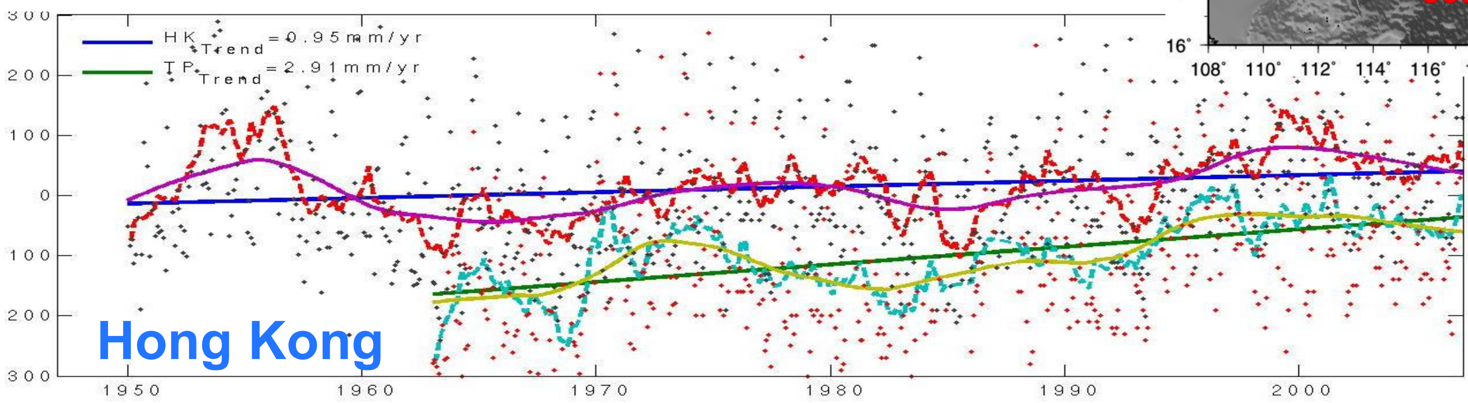
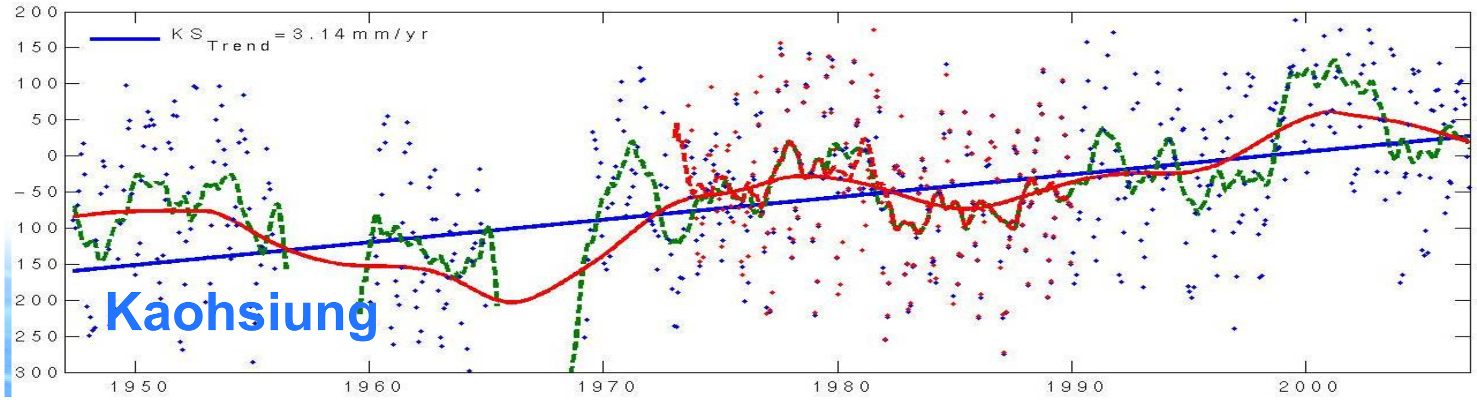
Sea level variability-tidal gauge



Trend of low-latitude stations





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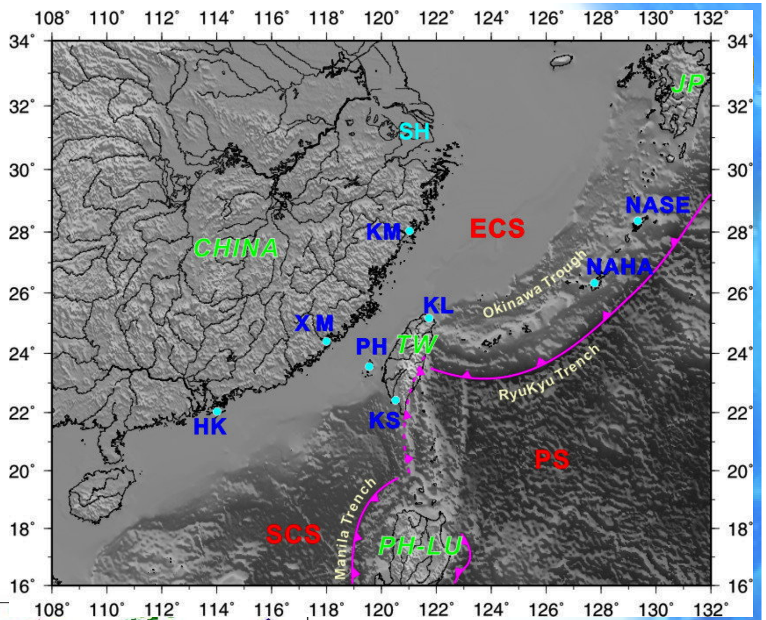
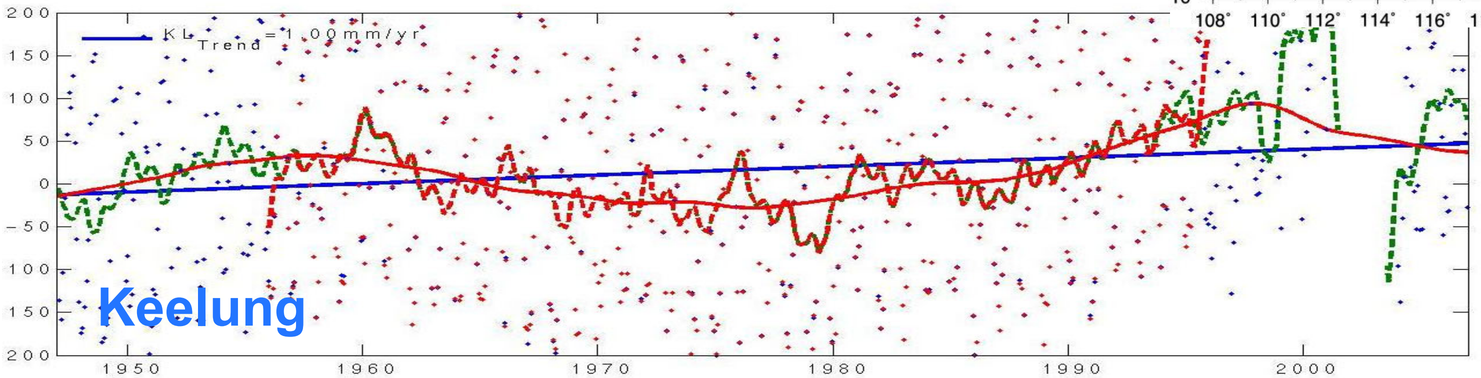
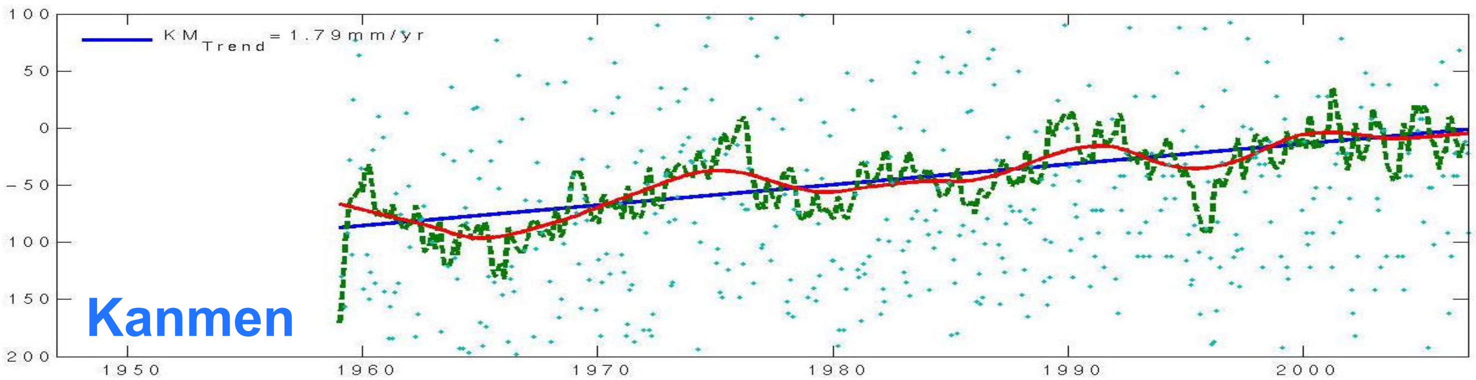
Sea level variability-tidal gauge



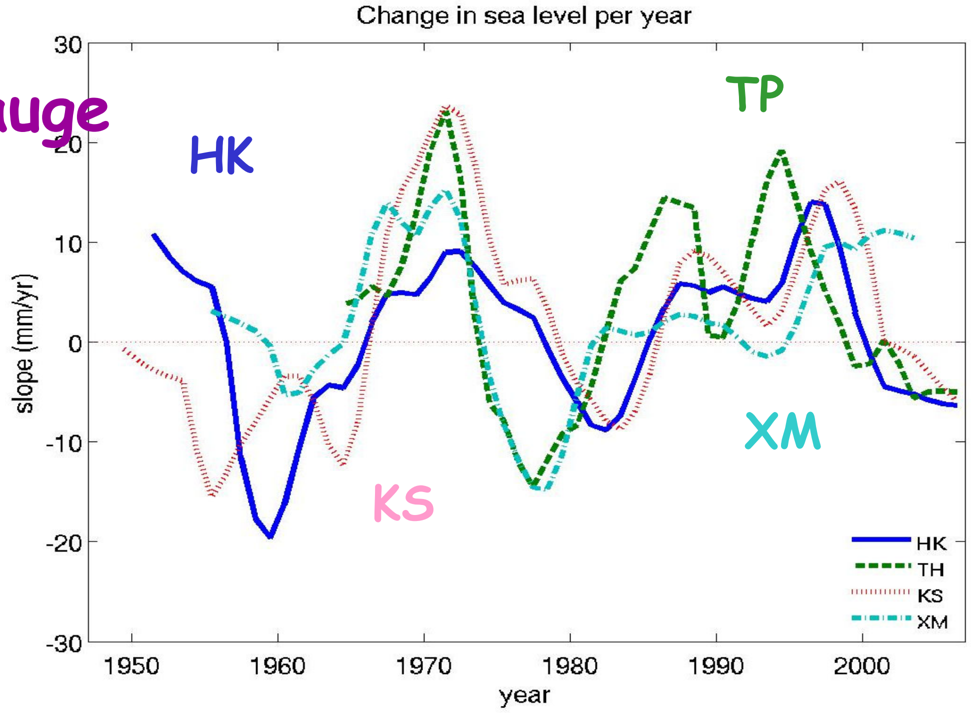
Trend of low-latitude stations



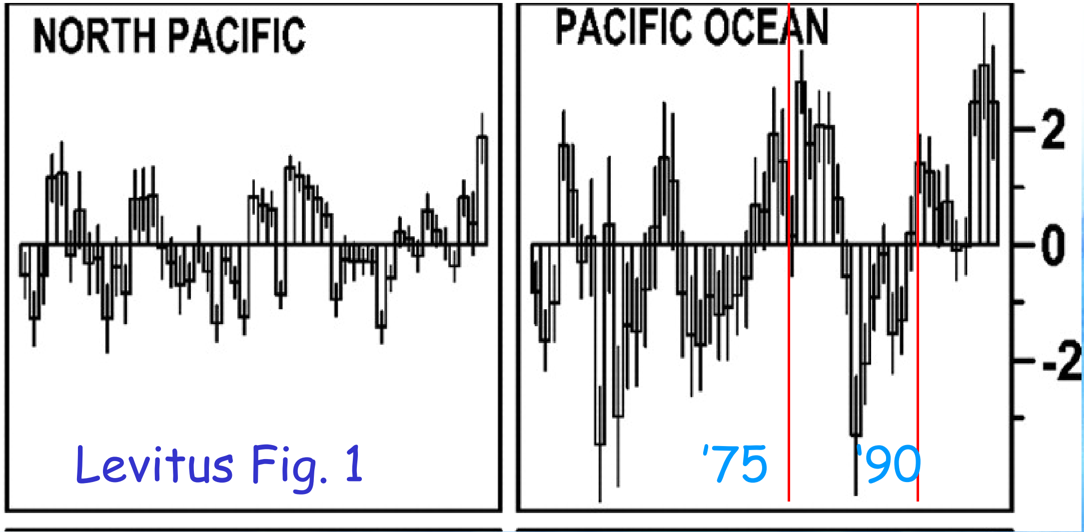


Sea level variability-tidal gauge

Yearly forward difference (mm/yr)



-Recent sea level trend : in increasing phase from 1993



	1993~2003	1961~2003	1955~2003	Entire periods
HK	4.0	2.1	0.2	0.6(1951~2006)
KS	7.3	4.9	3.4	1.9(1949~2006)
XM	7.8	2.7	2.3	2.3(1955~2003)
PH	17.1	4.3	11.0	10.5(1956~2006)
KL	-0.34	0.8	0.5	0.8(1948~2006)
KM	2.0	1.7	-	1.4(1960~2007)
NS	4.3	0.4	-	-0.1(1959~2007)
NH	3.5	2.51	-	3.4(1968~2007)
	5.7	2.4	3.5	

Unit: mm/yr

ea level trends from different studies.

Steric sea level change with errors (mm yr-1)	Period	Depth range (m)	Data Source
0.40 ± 0.09	1955–1998	0–3,000	Levitus et al. (2005b)
0.33 ± 0.07	1955–2003	0–700	Levitus et al. (2005b)
0.36 ± 0.06	1955–2003	0–700	Ishii et al. (2006)
1.2 ± 0.5	1993–2003	0–700	Levitus et al. (2005b)
1.2 ± 0.5	1993–2003	0–700	Ishii et al. (2006)
1.6 ± 0.5	1993–2003	0–750	Willis et al. (2004)
1.8 ± 0.4	1993-2003	0-700	Guinehut et al. (2004)

Source	Sea Level Rise (mm yr-1) 1961–2003	1993–2003
Thermal Expansion	0.42 ± 0.12	1.6 ± 0.5
Glaciers and Ice Caps	0.50 ± 0.18	0.77 ± 0.22
Greenland Ice Sheet	0.05 ± 0.12	0.21 ± 0.07
Antarctic Ice Sheet	0.14 ± 0.41	0.21 ± 0.35
Sum	1.1 ± 0.5	2.8 ± 0.7
Observed	1.8 ± 0.5	3.1 ± 0.7
Difference (Observed –Sum)	0.7 ± 0.7	0.3 ± 1.0

IPCC AR4 (Table 5.2, 5.3)

Mean SLR is larger than the global mean

5.7 mm/yr v.s. 3.1 mm/yr (1993-2003), 2.4 mm/yr v.s. 1.8 mm/yr (1961-2003)

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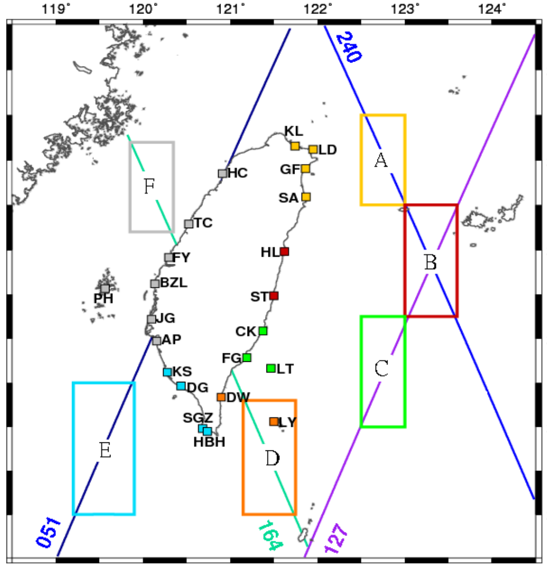
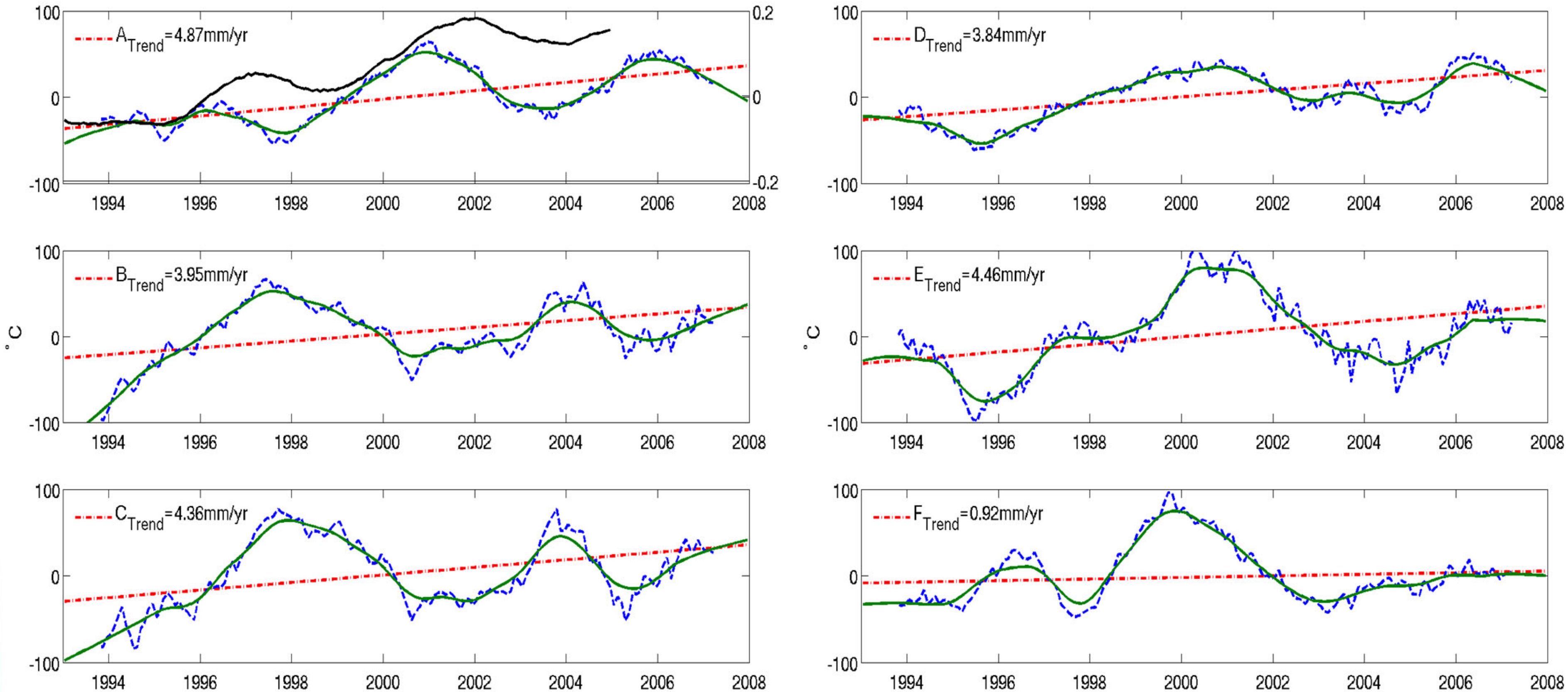
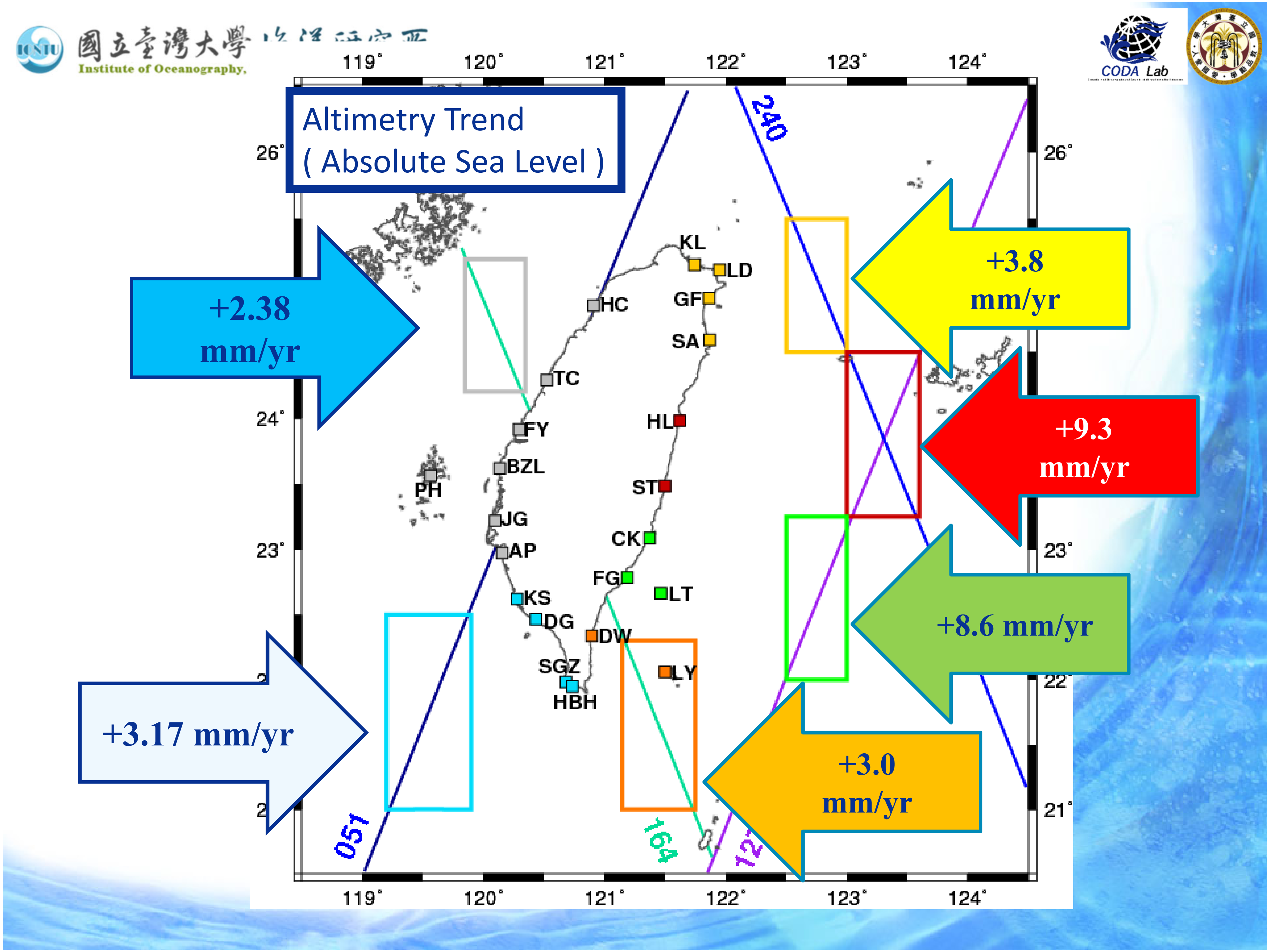
Sea level variability-RADS satellite altimetry



14°C isotherm temperature anomaly (Palmer et al., 2007)





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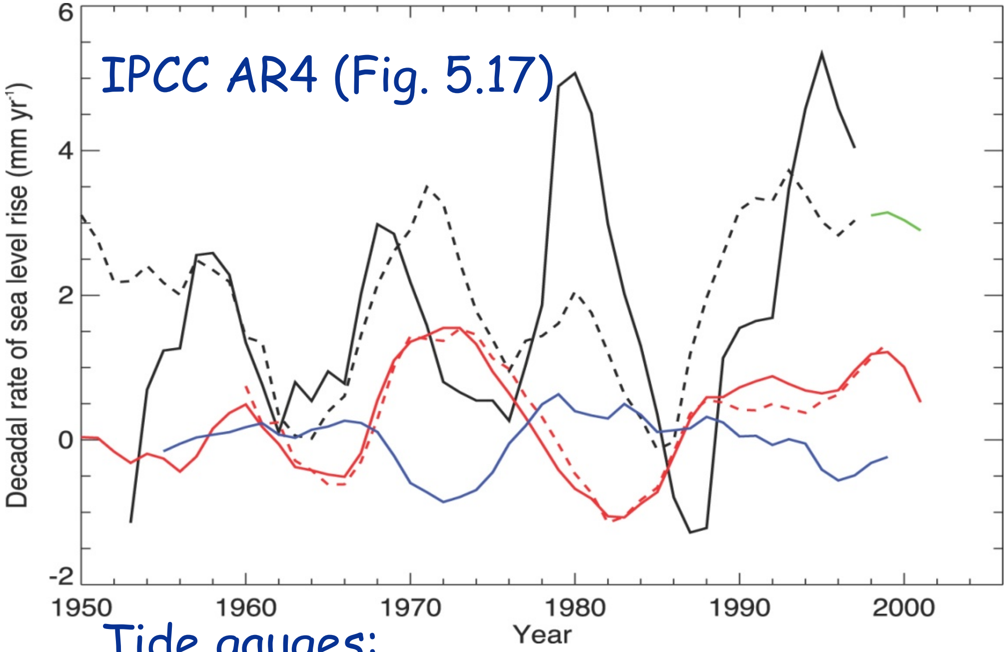
Altimetry Trend
(Absolute Sea Level)
+2.38 mm/yr
+3.17 mm/yr
+3.8 mm/yr
+9.3 mm/yr
+8.6 mm/yr
+3.0 mm/yr
KL
LD
GF
SA
HC
TC
FY
BZL
PH
JG
AP
KS
DG
SGZ
HBH
HL
ST
CK
FG
LT
DW
LY
240
051
164
119˚
120˚
121˚
122˚
123˚
124˚
26˚
24˚
23˚
22˚
21˚

Comparison with the global trends



Tide gauges:

Holgate and Woodworth (2004), solid black

Church and White (2006), dashed black

Satellite:

Dazenave and Nerem (2004), green

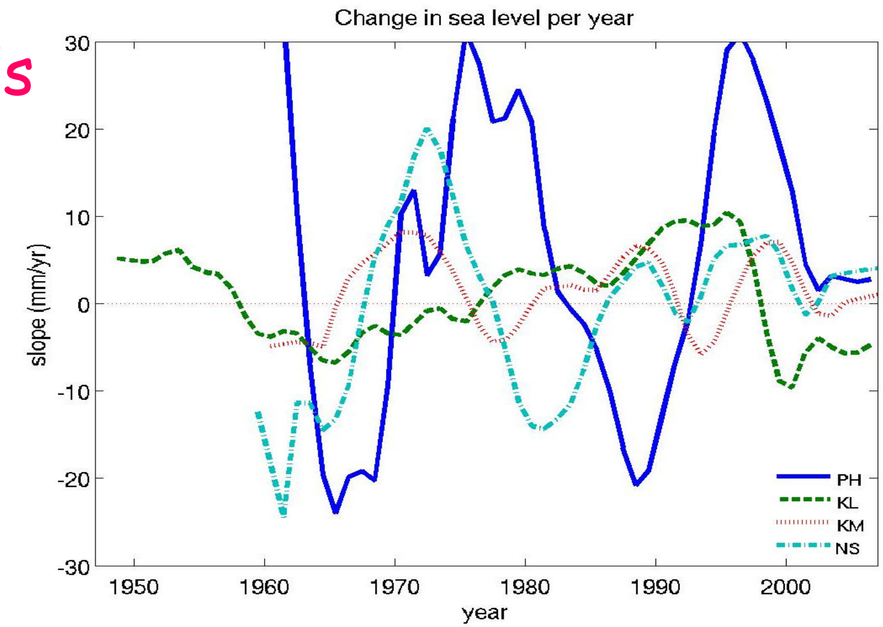
Thermal expansion:

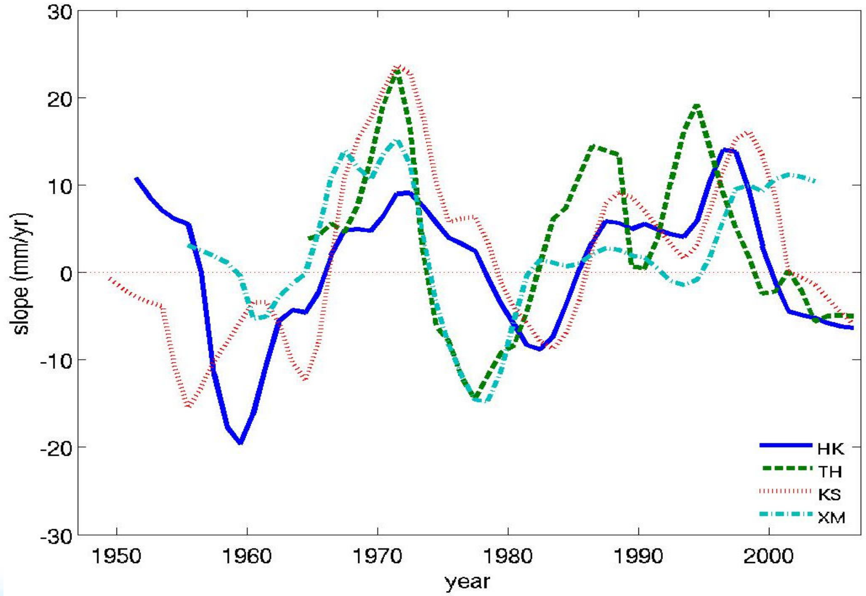
Ishii et al. (2006), solid red

Antonov et al. (2005), dashed red

Climate-driven land water storage

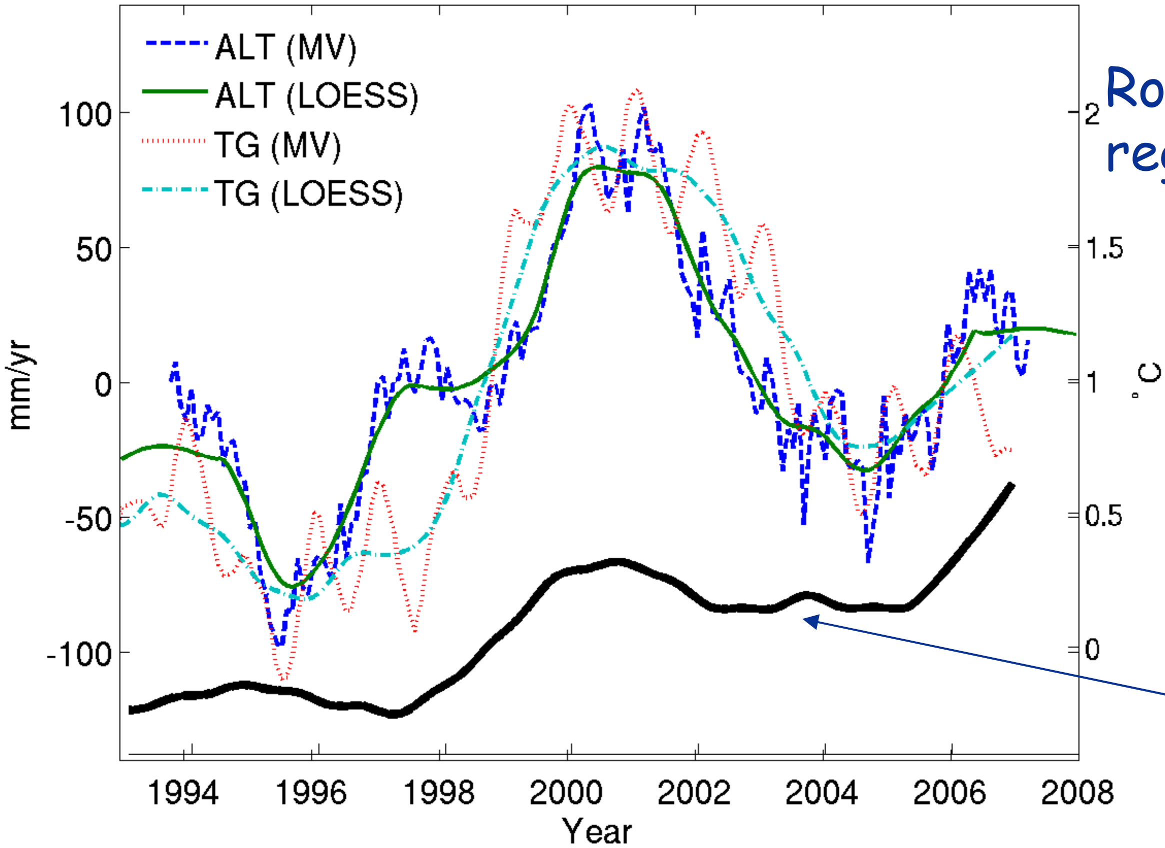
Ngo-Duc et al. (2005), blue





Comparison between tide gauges and altimetry

Tide gauge (KS): 4.5 mm/yr, 3.1 mm/yr
Altimetry (E): 7.5 mm/yr, 3.6 mm/yr



Robust linear regression

LOESS

ALT trend - TG trend = Vertical Land motion

Temperature anomaly in northeast of SCS (Ishii et al., 2006)

Correlation >0.9

WHAT CAN WE DO USING THE COUPLED MODELS?

Integrated ocean-atmos. coupled modelling system

- Global ocean-atmos. coupled modelling system
  - Downscaling to the regional ocean model

- High-resolution ocean-atmos. coupled regional model in the ECS and SCS

Global Ocean-atmosphere coupled Model in CWB

Initial condition from HYCOM

CWBGFS Coupled System

2 hour Coupling

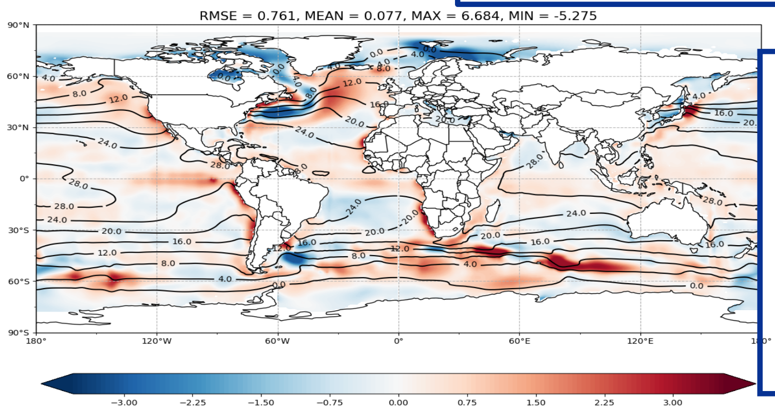
Ocean Model
TIMCOM
global
0.234° (0.1° in tropics)
46 levels
Grids:1536x576x46

Wind, radiation, prec. etc

SST, surface velocity

Atmospheric Model
TCo383
0.232° (~23 km)
72 levels
Grids:1552x768x72

Ocean Model
TIMCOM
regional
0.125° , 26 levels
Grids:406x488x26



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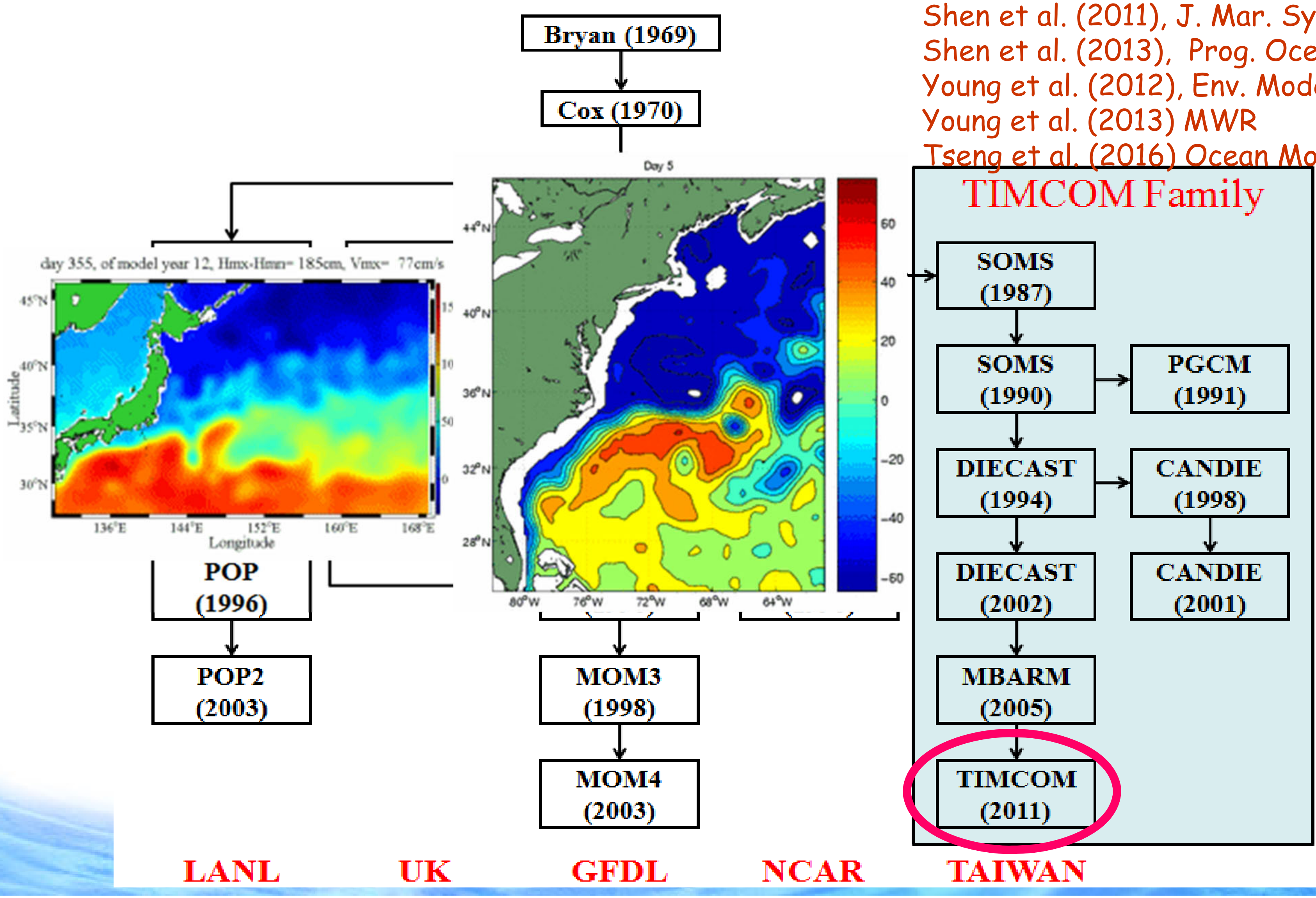
Taiwan Multi-scale Community Ocean Model

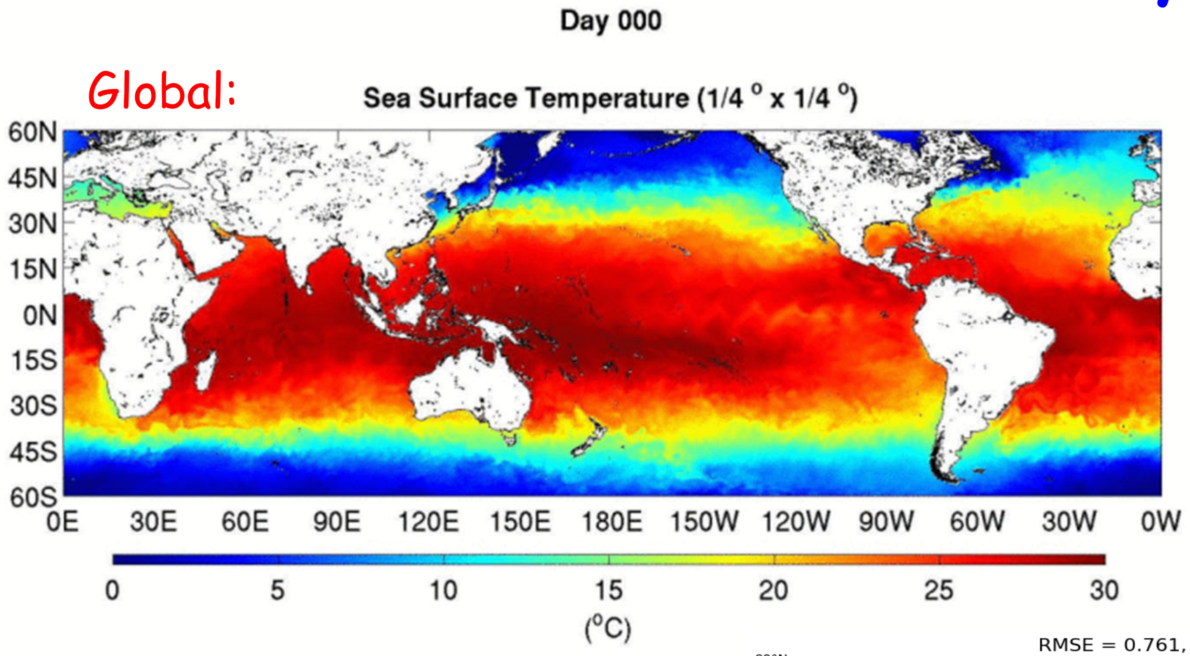
http://coda.oc.ntu.edu.tw/coda/research/timcom/

Tseng et al. (2012), Prog. Ocean
Tseng and Chien (2011), Comp. Fluids
Shen et al. (2011), J. Mar. Sys.
Shen et al. (2013), Prog. Ocean
Young et al. (2012), Env. Modell. Soft.
Young et al. (2013) MWR
Tseng et al. (2016) Ocean Modell.



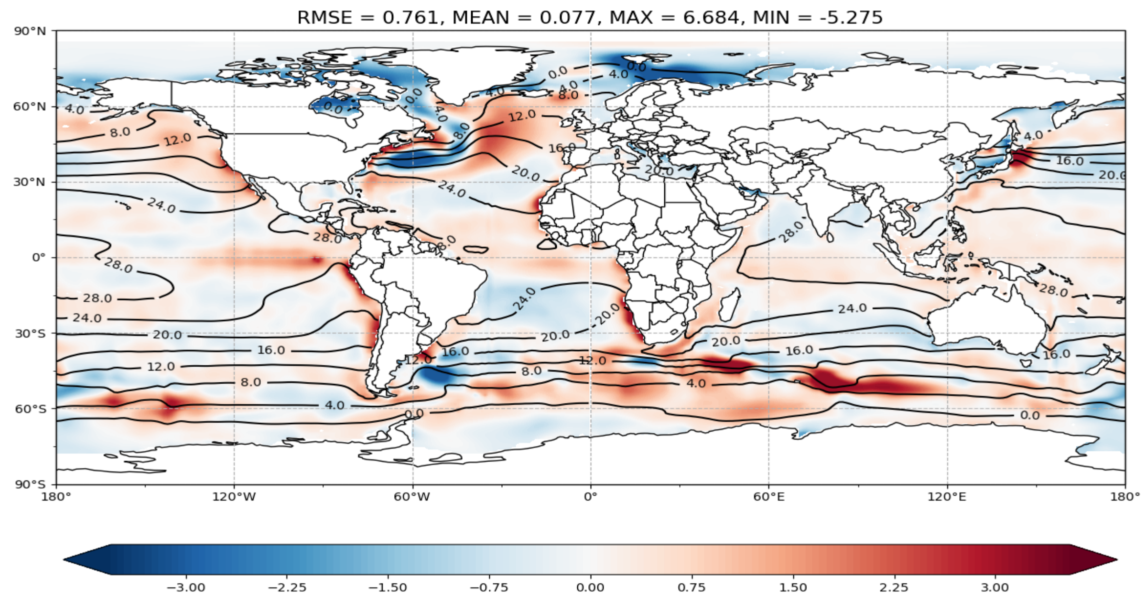
Taiwan Multi-scale Community Ocean Model

Global:



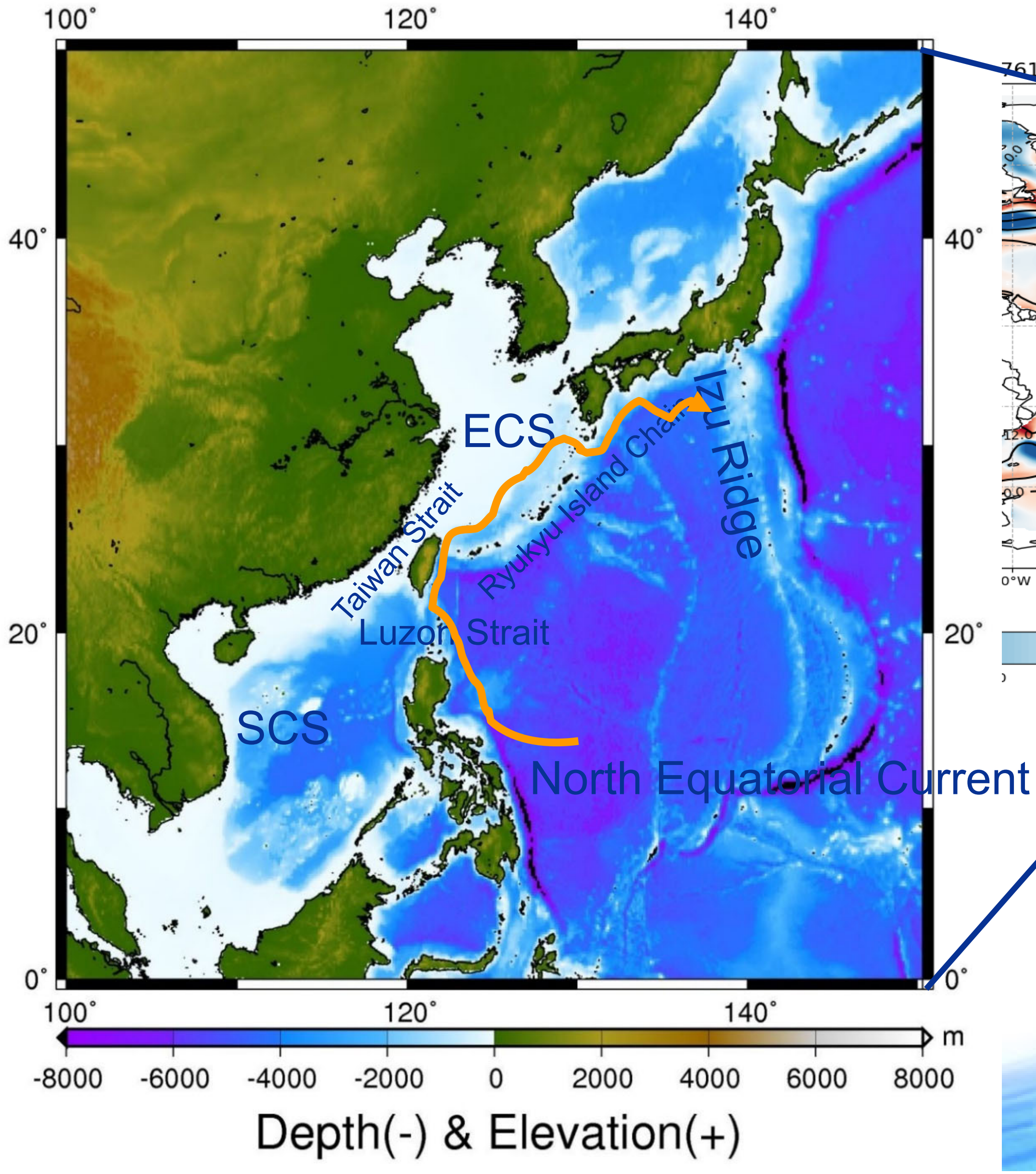
- 30s GEBCO bathymetry
- KPP vertical mixing
- GM meso-scale parameterization
- Initial Temperature and Salinity from HYCOM

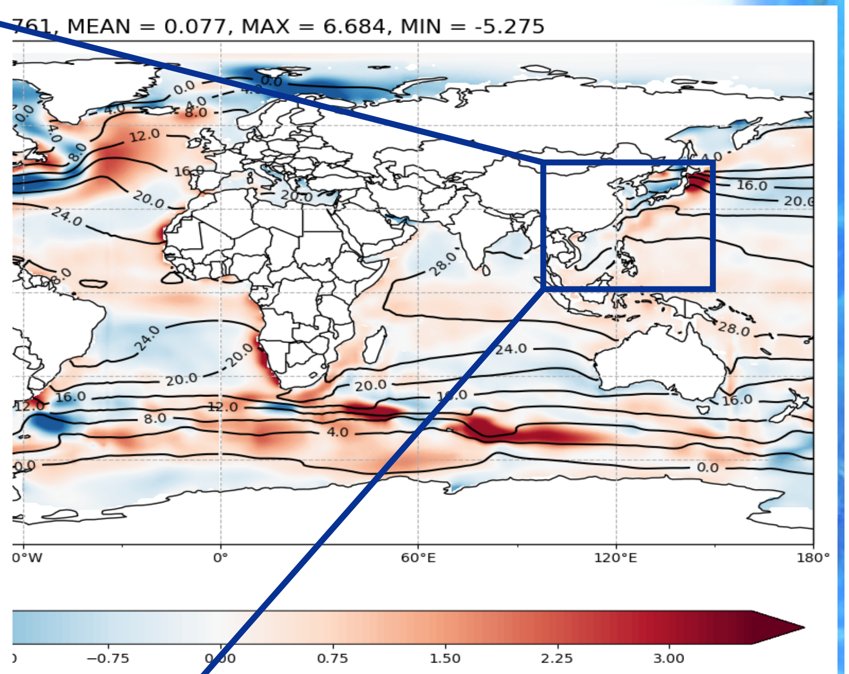
- 90°S-90°N
- Primitive, hydrostatic equation with free surface
- Fourth-order numerics combined Arakawa A and C-grid (1977)



Tseng and Chien (2011)

Taiwan Multi-scale Community Ocean Model





Regional:

- *0°-50°N and 100°E-150°E*
- *30s GEBCO bathymetry +200m Taiwan ODB*

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Taiwan Strait Currents (model)

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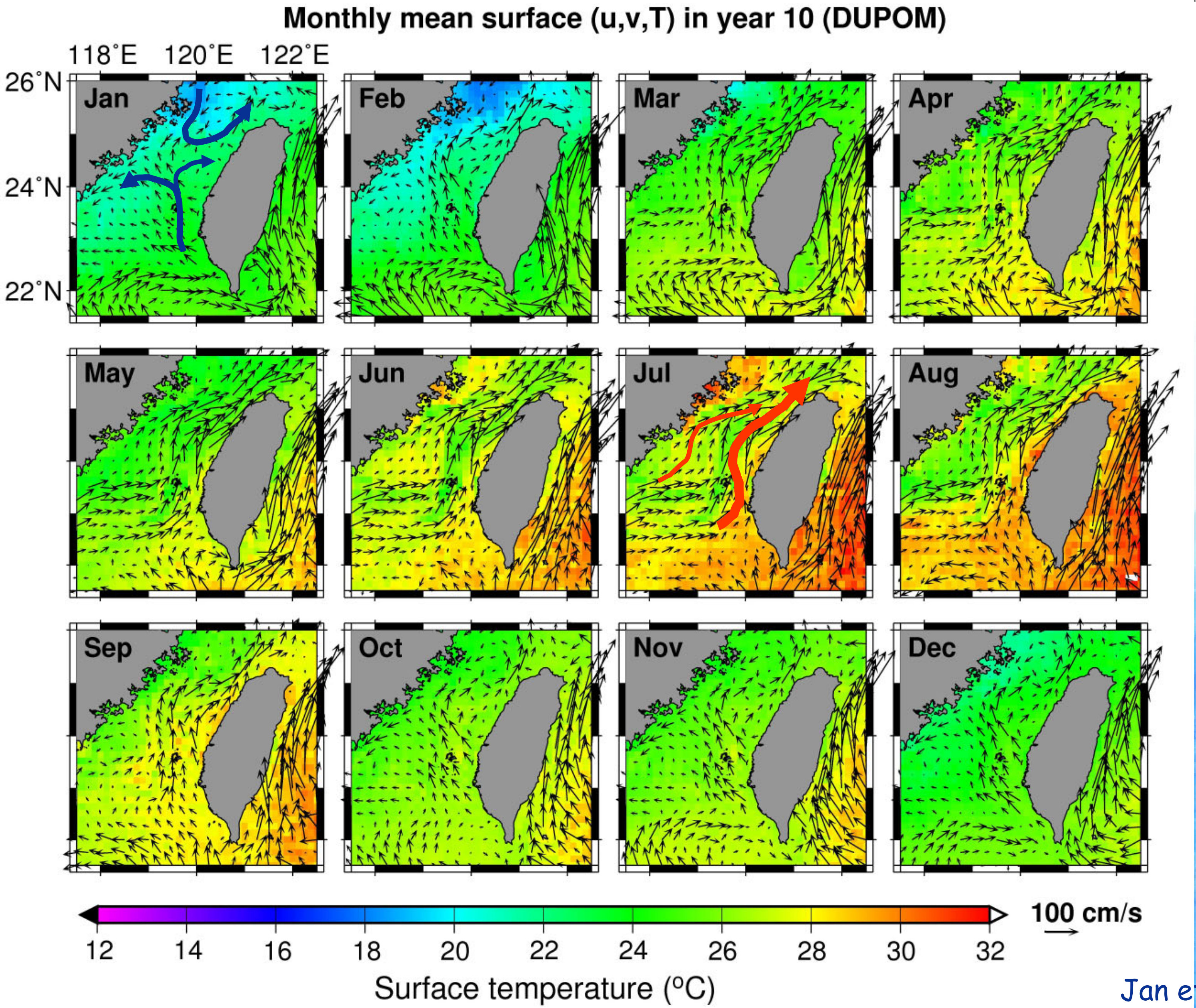
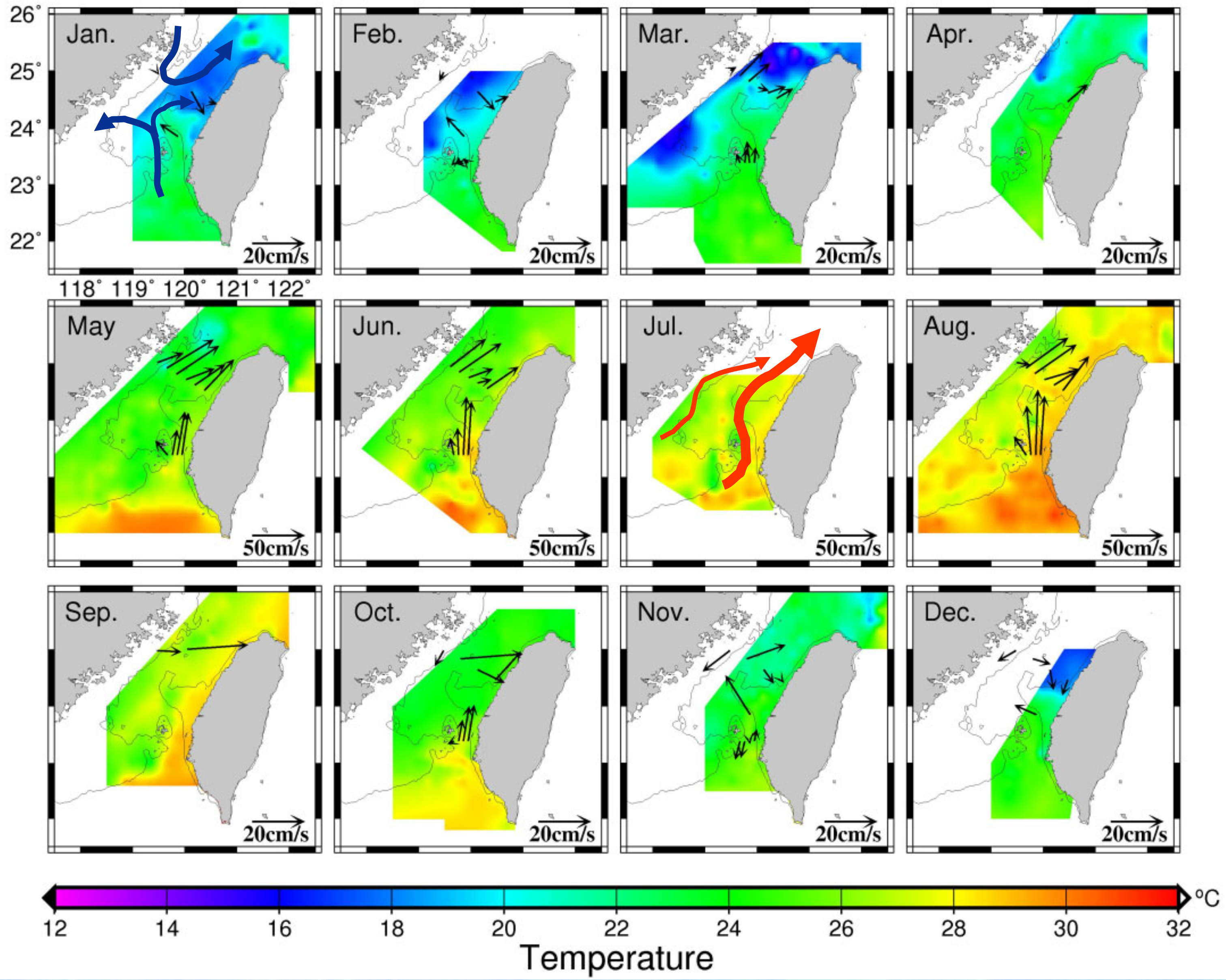


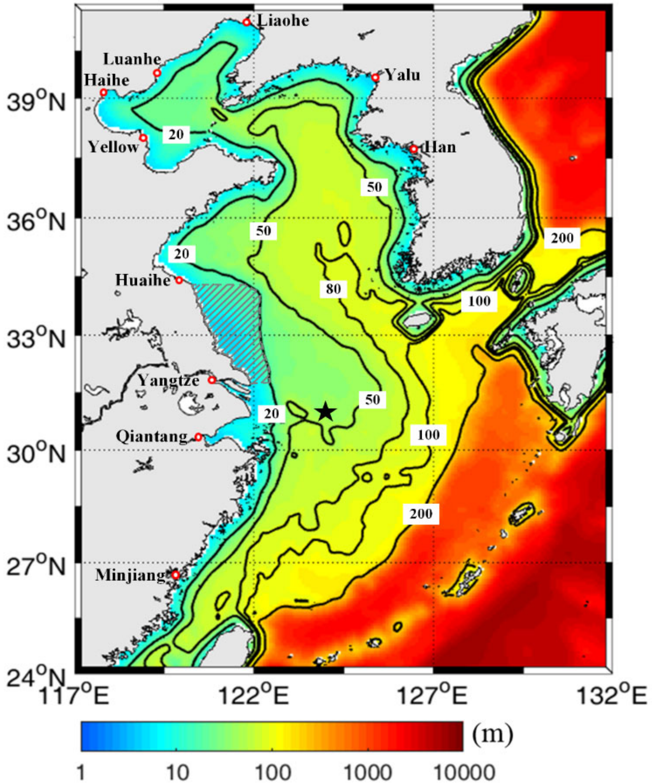
Jan et al. (2010)

Taiwan Strait Currents (obs)

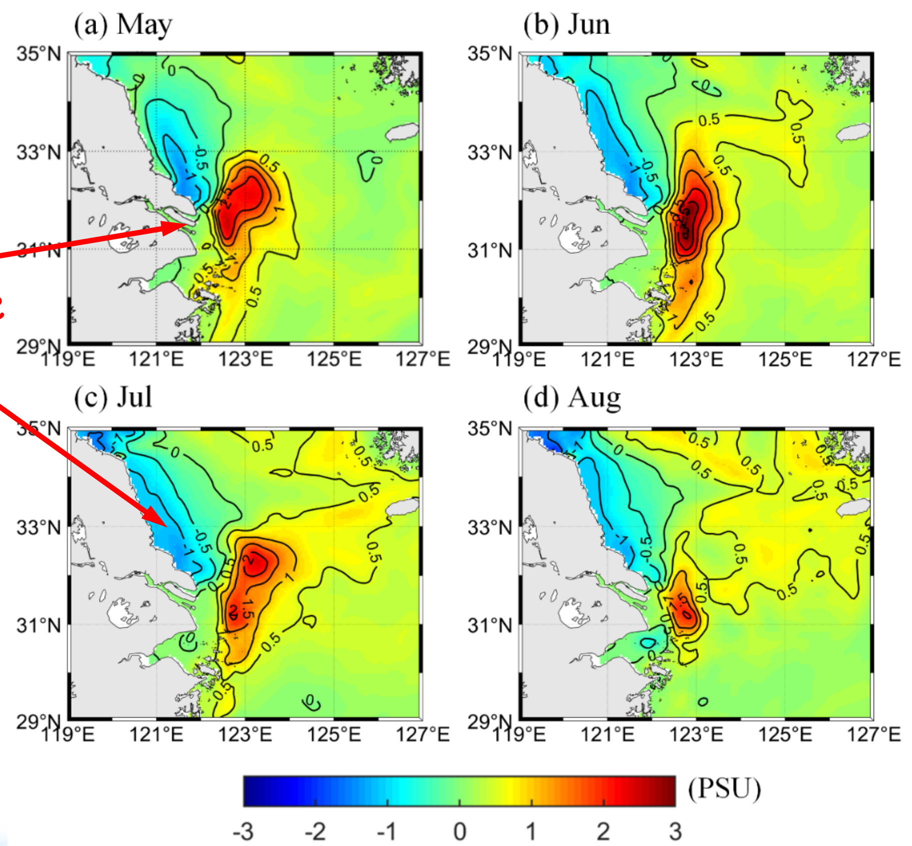


HIGH-RESOLUTION OCEAN-ATMOS. COUPLED REGIONAL MODEL IN THE ECS AND SCS

Diurnal forcing causes summer salinity dipole in the ECS



Monthly mean differences of SSS (diurnal-daily)



dipole-like pattern

Yu et al. (2019)

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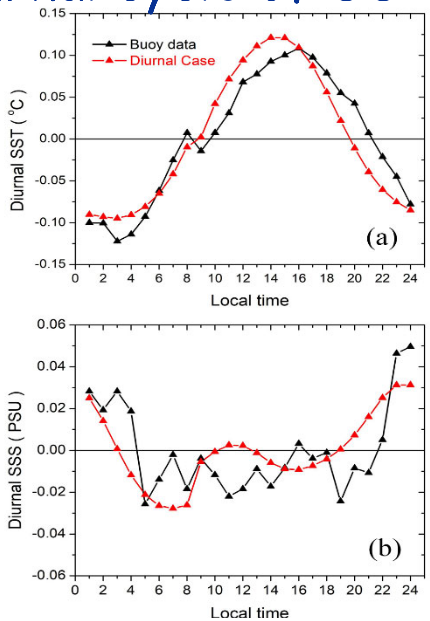
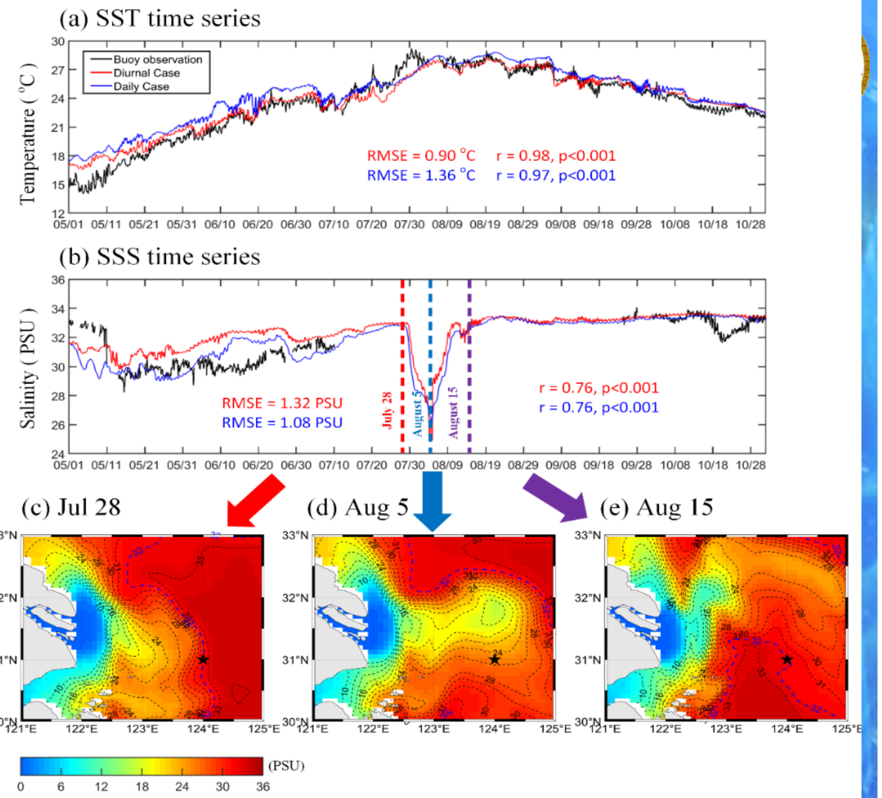
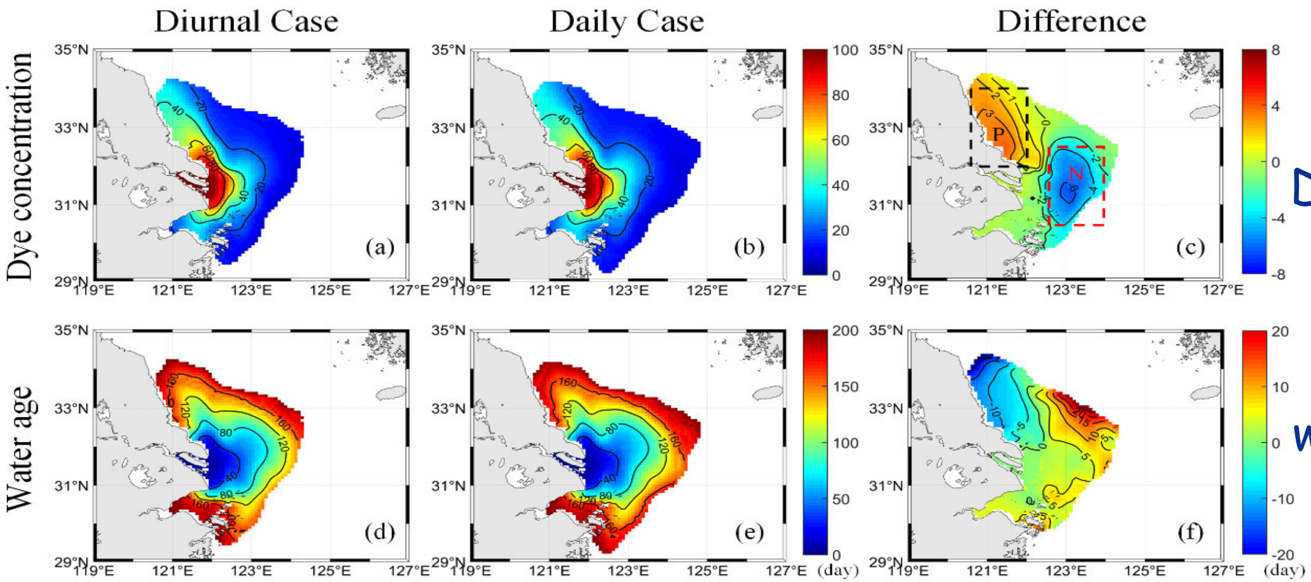
Diurnal cycle of SST and SSS







Dye tracer concentration

water age of Yangtze River

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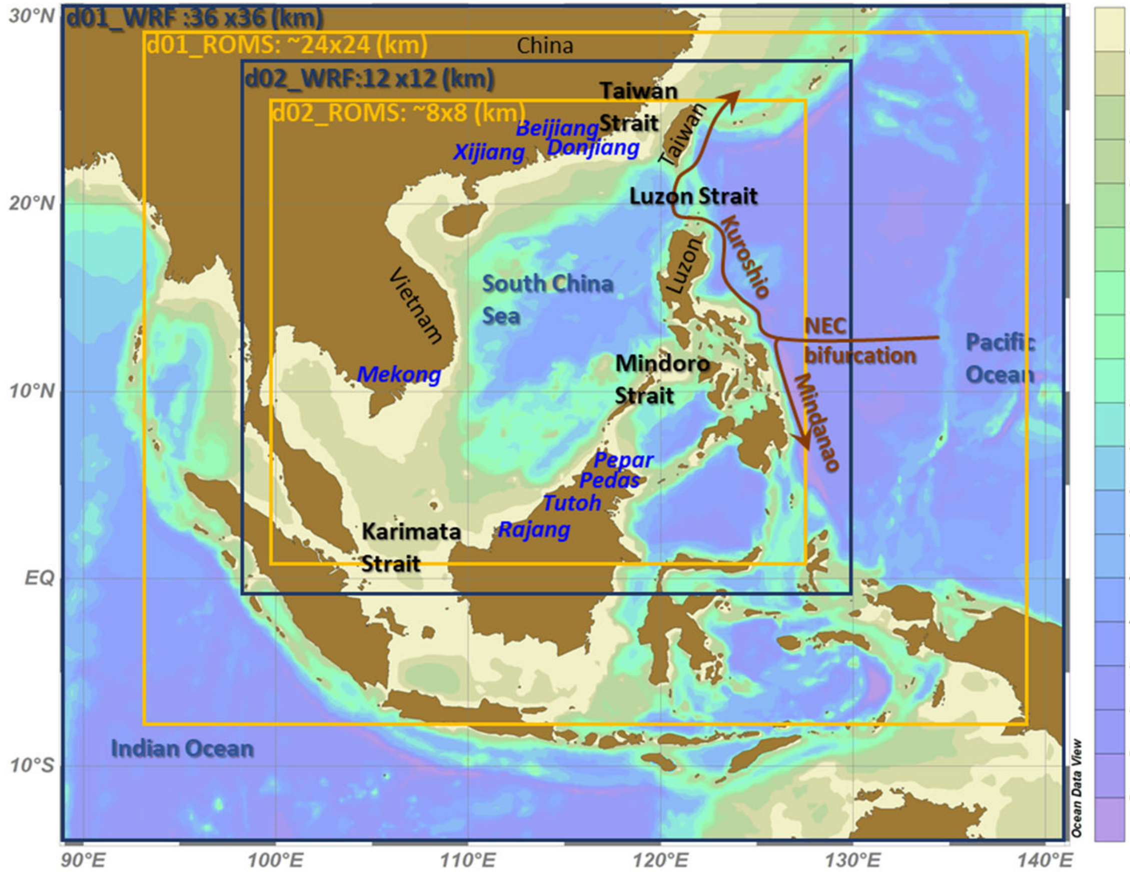
ENSO impacts on the SCS



Weather Research and Forecasting Model (WRF)
Domain 1 : 36x36(km)
Domain 2 : 12x12(km)
Vertical : 36 levels

Initial/lateral BC: NCEP FNL Operational Model Global Tropospheric Analyses

Regional Ocean Modeling System (ROMS)
Domain 1 : 24x24 (km)
Domain 2 : 8x8 (km)
Vertical : 25 levels

Initial/lateral BC: HYCOM + NCODA Global 1/12° Reanalysis

EXP1 2015/11-2016/6 El Niño
EXP2 2011/11-2012/6 La Niña

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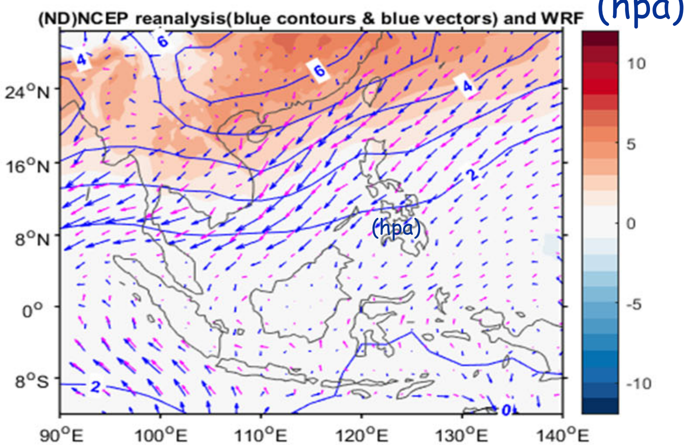
Model validation-the low level circulation

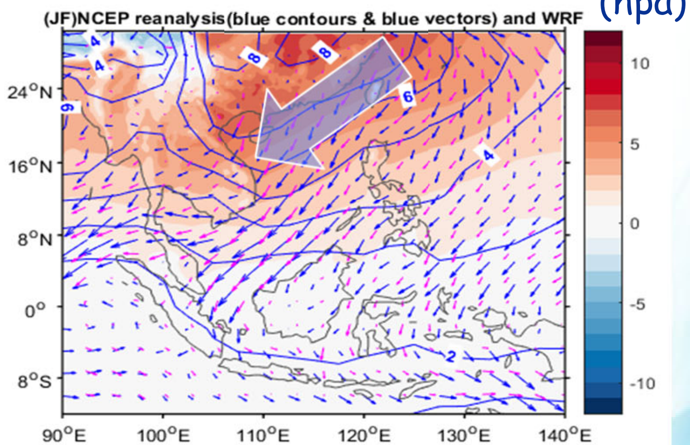
Blue contours and vectors: NCEP reanalysis.
Shaded color and pink vectors: RCM

The El Niño case (2015/11-2016/6)

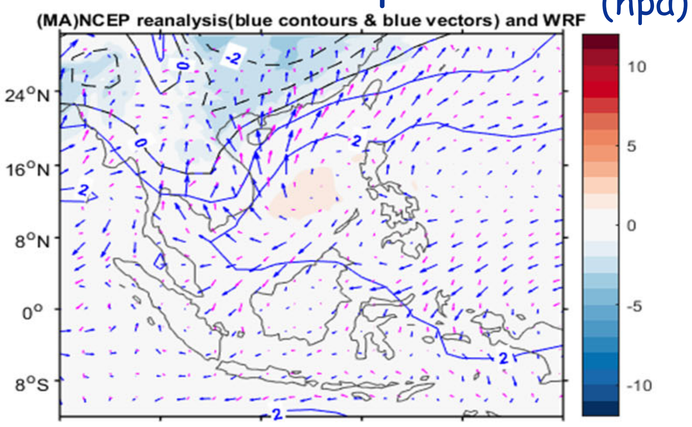
Nov-Dec



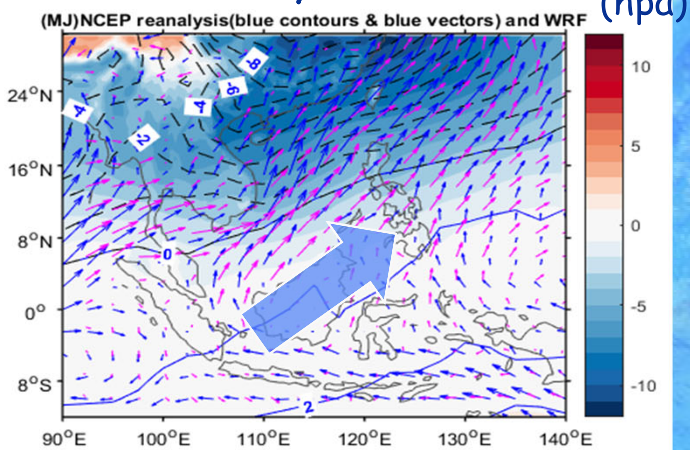
Jan-Feb



Mar-Apr



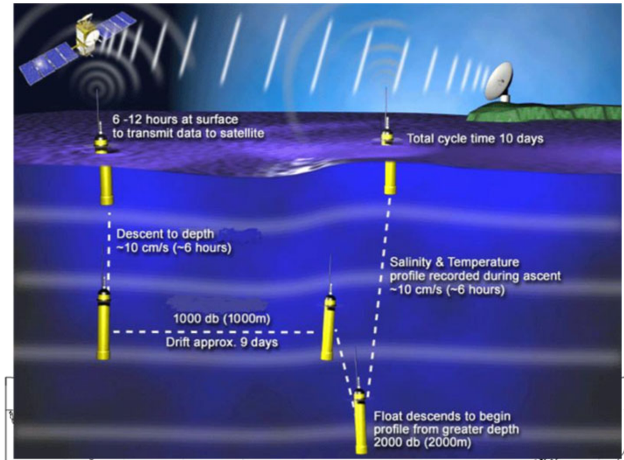
May-Jun

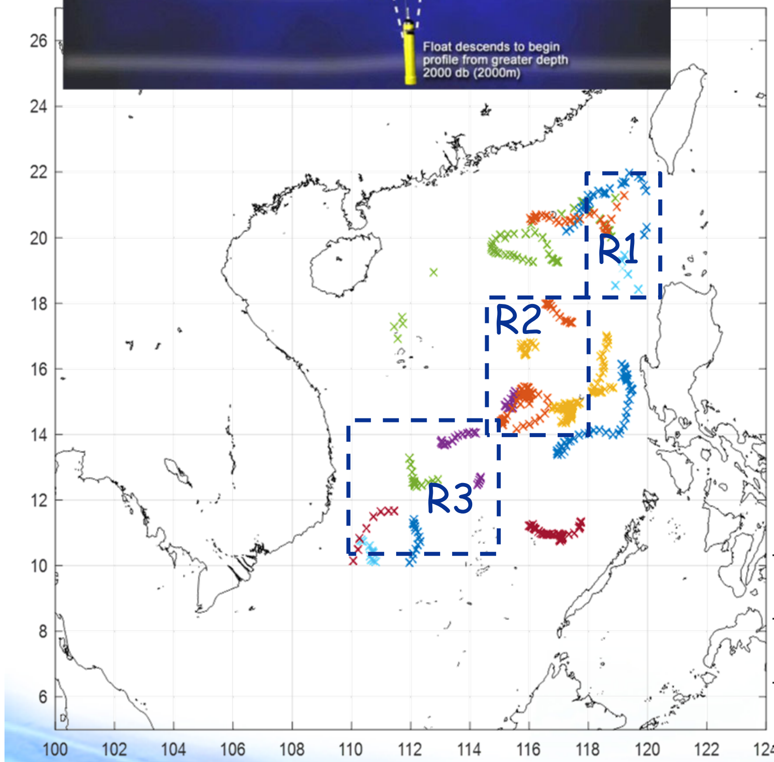


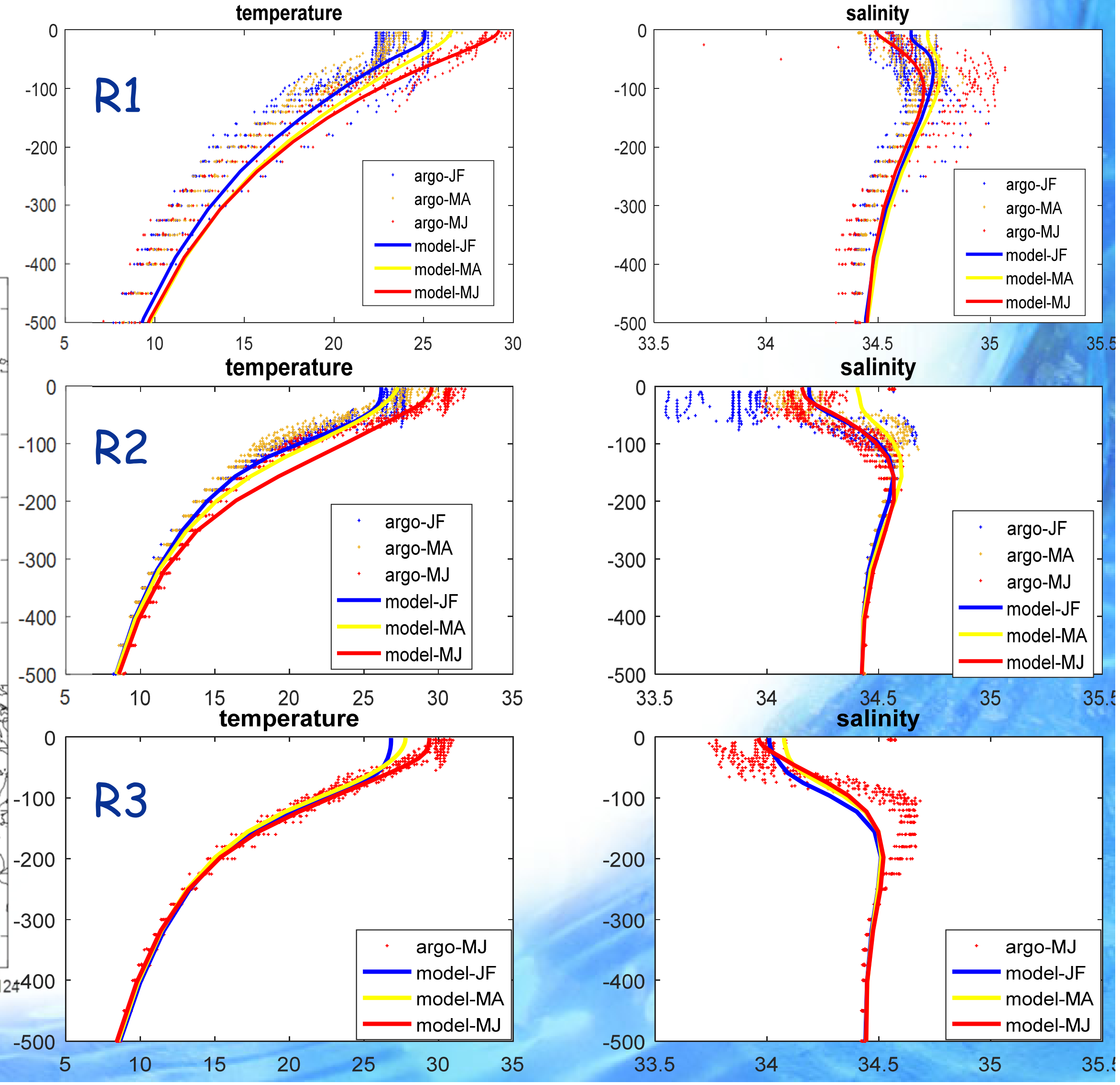
Kuo and Tseng (2020)

Model validation-TS profiles vs Argo Floats

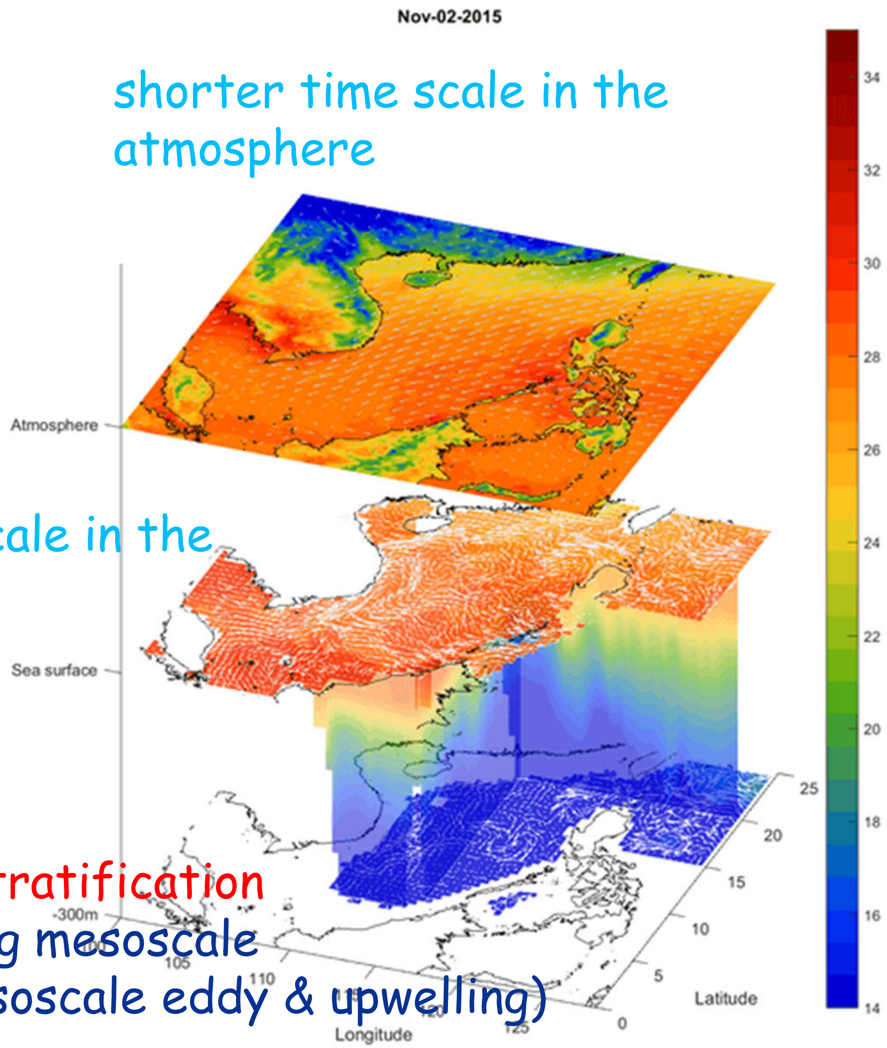
Well capture the Argo float observation







Kuo and Tseng (2020)



shorter time scale in the atmosphere

longer time scale in the ocean

1.Stronger stratification
2.Long-lasting mesoscale features(mesoscale eddy & upwelling)

1.Weaker stratification in the Pacific
2.Westward propagating Rossby waves, mesoscale eddies and Kuroshio intrusion

See more in

Kuo, Y.-C., **Tseng*, Y.H.** (2020), "Impact of ENSO on the South China Sea during ENSO decaying winter-spring modeled by a regional coupled model (a new mesoscale perspective)," *Ocean Modell.*, 152, 101655.

Kuo, Y.-C., **Tseng*, Y.H.** (2021), "Influence of anomalous low-level circulation on the Kuroshio in the Luzon Strait during ENSO," *Ocean Modell.*, 159, 101759.

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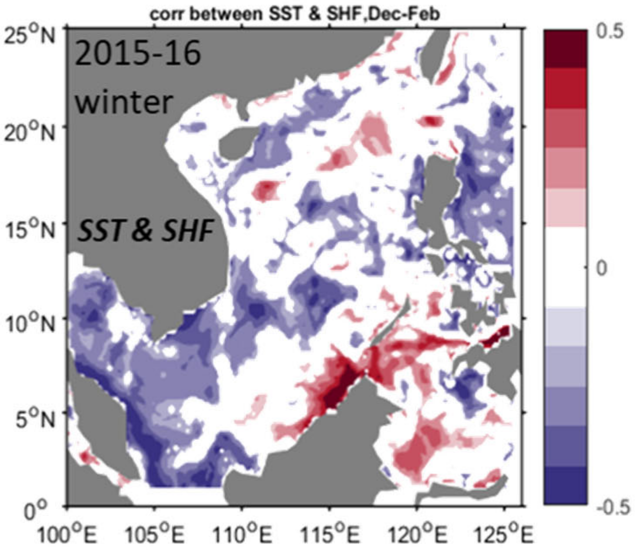
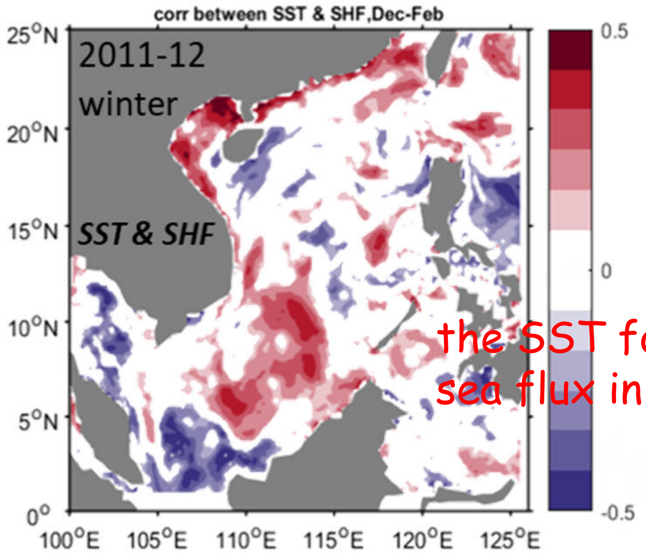
2015 El Nino

2011 La Nina

Correlation between SST & SHF

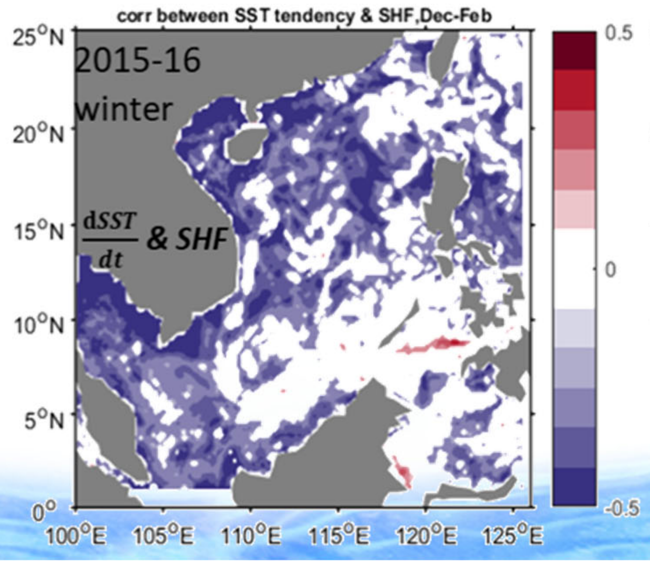


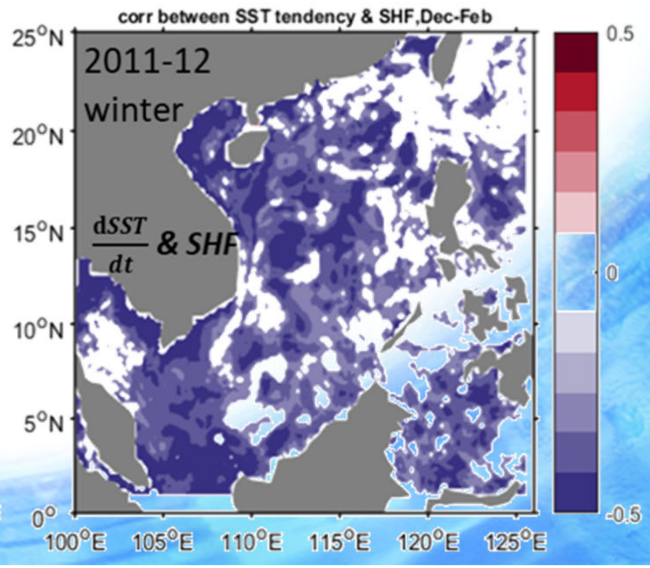


the SST forces the air-sea flux in southern SCS

atm. forcing dominates the air-sea flux in the northern SCS

Correlation between $\frac{dSST}{dt}$ ***& SHF***





Summary

- Temperature, heat content, sea level changes are subject to the interannual and decadal variability
- Global coupled model is required to provide better initial and boundary conditions for the regional model
  - Resolving the complicated ocean-atm interaction (including local air-sea interaction)
  - Accuracy, predictability, resolution, coupling frequency
- Importance of diurnal forcing (short-term)
- ENSO forcing (long-term) on the air-sea condition

Thanks for Your Attention!